INTERNATIONAL HYDROGRAPHIC BUREAU

A SUMMARY

OF

ECHO SOUNDING APPARATUS

Special Publication N° 33

MONACO

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PREFACE

Since its foundation, the International Hydrographic Bureau has endeavoured to collate all useful information concerning the new technique of echo-sounding, and the details of the important progress effected in this branch have been the subject matter of many articles inserted since 1923 in the various volumes of the Hydrographic Review *published half-yearly by the Bureau.*

Now that the evolution of the new sounding methods has reached an important development in navigation, in oceanography and more especially in hydrography, we propose, in the following pages, to give a summary and a general account of echo-sounding principles, methods, apparatus, together with their practical application realised up to date.

We would add that the reader will find more detailed information concerning the methods, the problems raised in this connection and the development of the various appliances reviewed, in the descriptions given either in the Hydrographic Review *or in the pamphlets written by the authors themselves, by the manufacturers, or published by the different Hydrographic Offices, and also in the various publications of the International Hydrographic Bureau.*

The few theoretical notions to which we have been obliged to limit our report cannot be considered as a full and definite account of a technique which is far from its final development and which is, therefore, subject to important and frequent improvements.

A bibliography at the end of this Manual shows the works to which we have amply referred in order to group in this pamphlet the minimum data which is required to obtain a general knowledge on the new problems involved by echo-sounding as applied to oceanography and to coastal hydrography.

Commander H. BENCKER,
Technical Assistant of the I.H.B.

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I. Historical Notes on Echo Sounding.

At the time of the 1st International Hydrographic Conference in London, in 1919, echo-sounding methods utilising the propagation of sonic waves in sea water, were just emerging from the experimental stage, but, since then, devices based on the properties of the echo have been commonly used for determining the depth of the sea.

However, the idea of utilising the great permeability offered by the sea water medium to the propagation of sonic waves is not a new one and had already appealed to many physicists. In fact, about 1807, a proposal to utilise the propagation of sound for deep sea soundings, is attributed to Jean François Arago. In 1837, Ch. Bonnycastle made an attempt to sound the bottom of the sea by echo-sounding; in 1841, J.D. Colladon, with a powerful sub-marine bell, obtained sonic transmissions in sea water on a range of 20 nautical miles. The great American oceanographer, Matthew Fontaine Maury, alludes in his book "The Physical Geography of the Sea", to the unsuccessful attempts made in 1855 to determine the depth of the sea: "by exploding petards or ringing bells, the echo of reverberation from the bottom might, it was held, be heard and the depth determined from the rate at which sound travels through water". In 1888, Mr. Banaré advocated the use of microphones to detect with greater ease sub-marine signals, a device which was perfected by Gray and Mundy in 1902.

After the loss of the liner "Titanic" in April 1912, through a collision with an iceberg, the study of the location at sea of these unexpected dangers, by means of sub-marine sonic waves, was actively resumed. In 1912, Doctor Alexander Behm obtained photographic records of echoes emanating from the sea bottom in the Bay of Heikendorf, following experiments made on board the "Otter", by the Laboratorium für Unterwasserschall der Torpedo und Mineninspektion of Kiel". This process was patented on 23rd July 1913. Powerful sub-marine transmitters were manufactured, such as the American oscillators of Professor Reginald A. Fessenden, of Boston, which were tested in March 1914 during the ice patrol. Sub-marine warfare also opened up a new field of research in this branch, more especially to directional listening-in by means of hydrophones and to the horizontal sound ranging of noises at sea, such as screw noises and their reflection from the bottom of the sea, this leading naturally to sounding.

The first patents relative to echo-sounding, taken out by Doctor h.c. Alexander Behm in Germany, Professor Reginald A. Fessenden in the United States of America, and by Professors Langevin and Florisson in France date back to the years 1912 and 1914.

In Great Britain, the first practical applications of echo-sounding were effected under the auspices of Admiral Sommerville, and of Mr. B.S. Smith, Director of the Admiralty Scientific Research and Experiment Department, at the Teddington Laboratory.

In 1916, an echo-sounding apparatus was tried out on the Canadian surveying vessel *Cartier*. In 1917, Doctor Behm obtained the first sounding in fresh water in the Lake of Ploem. Also in 1917, Professor Langevin invented the piezo-electric ultra-sonic projector which was applied in France at the beginning of 1919 to vertical sounding. In 1918, ships of the American Navy applied to sounding their microphonic apparatus for sub-marine listening-in (U.S.S. *Von Steuben*, U.S.S. *Breckenridge*). In May 1919, the French Hydrographic Department carried out echo-soundings in the Casquets deep in a depth of 60 metres and at a speed of 10 knots. In August 1919, the cable-ship *Charente* obtained soundings at 4.000 metres in the Bay of Biscay by means of detonators. In October 1920, the Centre d'Etudes de Toulon was successful in obtaining the first line of ultra-sonic soundings in the offing of Nice.

But the first important and really practical applications of sound to sounding only took place in 1922. In April 1922, the French Hydrographic Department obtained, with an apparatus of Ingénieur hydrographe Marti, a line of sonic soundings across the Mediterranean for the cable from Marseilles to Philippeville. The sloop *Ville d'Ys* obtained a line of sonic soundings between Norway and Iceland with an L.F. ultra-sonic sounder, spark transmission. From the 20th to the 29th June 1922, a profile of the North Atlantic Ocean from Newport to Gibraltar, and in July 1922, from Gibraltar to Port Said, was obtained on the U.S.S. *Stewart*, by means of the new acoustic sounder type 2 (Sonic Depth Finder, type S.E. 1378) recently perfected by Dr. H.C. Hayes of the Engineering Experimental Station, Annapolis Naval Academy.

During the same year, the "Behm Echolot Gesellschaft" of Kiel put on the market a depth indicator described in the *Annalen der Hydrographie und Mar. Meteorologie*, vol. XI, 1922, with an indicating luminous scale and with a photographic record for great depths. Further, the first bathymetric chart entirely obtained with sonic soundings (5,000) was drawn up in December 1922, within 38 days, by the United States Hydrographic Office for the offing of the Californian coast (U.S. H.O. chart N° 5194. March 1923 edition) the sounding having been executed at the hitherto unknown speed of 900 sq. miles per day. This chart revealed that the bottom of the sea between the shore and the 2,000 fathom isobath (3,700 m.) was far more uneven than had been conceived from the few scattered soundings available up to that date.

Lastly, the expedition of the German exploration ship "Meteor" in the Southern Atlantic Ocean in 1925-27 provided the most extensive sounding work ever obtained, by the establishment of 14 transoceanic profiles comprising more than 67,430 soundings taken at approximately 34,000 stations with two echo-sounders.

It is also to sonic soundings that is due the discovery of the greatest known oceanic depth of 10,790 metres in the Mindanao deep, by the German cruiser *Emden* in April 1927.

Lastly, by means of echo-sounding diagrams recorded continuously, it is very easy to obtain an exact idea of the irregularities of the sub-marine floor. Thus on the edge of continental shelves, deep ravines have been found, shaped like large sub-marine canyons, which seem an extension offshore of river estuaries, and which remained undetected as long as the sounding lead alone was used for examining the sub-marine floor. In certain volcanic regions, it has also been possible to detect, by means of echo-sounding, small circular mounds protruding on the surface of the floor, and which seem evident testimony of ancient volcanic eruptions. Ridges or "ridens" have also been found on certain points of the bottom of the sea, constituted by material brought from certain channels or from the mouth of rivers and placed in a transverse position to the current.

And thus has been opened, thanks to the development of sonic soundings, a new era not only in the knowledge of the relief of the ocean bottom, but also in the processes connected with coastal hydrography, where the accuracy required in the apparatus adds technical difficulties which are now overcome.

All the modern exploring ships, all the surveying vessels and even sounding boats, are now fitted with recording apparatus adapted to the work effected, and each new year brings a more and more important contribution to the data collated with regard to the bathymetry of the seas.

All the great modern oceanographic expeditions, such as that of the *Marion* in 1928 (1,700 soundings); of the *Carnegie* in 1928-29 (1,496 soundings); of the Dutch surveying vessel *Willebrord Snellius* in the East Indies in 1929 (32,000 soundings); of the *Dana* in 1928-30 (7,976 soundings); of the *Emden* in 1928-31 (4,700 soundings); of the *General Greene* and ships of the Ice Patrol in the region of the Davis Strait, in 1931 to 1937 (9,000 soundings); of the *Karlsruhe* in 1932-37 (12,500 soundings); of the Byrd antarctic expedition in 1933-35 (2,723 soundings); of the Dutch sub-marine *K.XVIII* in 1934-35 (3,500 soundings); of the Egyptian exploring ship *Mabahiss* in the Indian Ocean in 1934 (4,500 soundings); of the British exploring ship *Discovery II* in the Antarctic since 1927; of the United States Navy auxiliary ship *Ramapo* during numerous crossings of the North Pacific from 1931 to 1936 (37,500 soundings), have provided abundant data regarding the sub-marine topography of seas and oceans.

All these oceanic soundings, as well as those effected by cable ships, liners, etc., are

collected by the International Hydrographic Bureau, as and when published, with a view to keeping up to date the General Bathymetric Chart of the Oceans published by the Bureau. The reduced scale of this publication in 24 sheets (24 in. × 40 in.), is 1 : 10,000,000 at the equator in Mercator projection. (Special Publication N° 30 of the International Hydrographic Bureau).

This Chart is kept permanently up to date by means of 1,001 plotting sheets, size 30 in. × 43 in., scale 1 : 1,000,000 at the equator in Mercator projection, covering the oceanic part of the globe, on which are recorded, after correction, all the soundings received by the Bureau. The number of oceanic soundings actually recorded (1939) by the International Hydrographic Bureau can be estimated at 300,000. More than half this figure corresponds to sonic soundings selected by original Hydrographic Departments.

II. General Principles of Echo-Sounding.

Any vibrating body, such as a sonic source, when immersed in the sea, generates elastic waves which are propagated with a velocity independent of the frequency of the vibrating movement and which is called in oceanography : the velocity of sound in sea water.

The general principle of the acoustic method consists, in general, of substituting for direct measurement of the depth itself an indirect evaluation thereof by means of the time taken by a sound wave to travel over this depth or, to be more exact, over a submarine path which is connected with the depth by a well known formula.

Thus for the measurement of a length, which up till now has been made with a fixed relative approximation, the measurement of an interval of time is substituted and it is absolutely necessary that this time measurement be precise.

With regard to Hydrography and Oceanography, it is generally the case that measurement must be made through sea-water, and therefore it is on the precise knowledge of the speed of propagation of sound through the sea that the problem is more or less based.

Generally speaking, sound travels through sea water at an average velocity of 1,500 metres (4,900 ft.) per second. Consequently, by the acoustic method of sounding, very great depths can be reached in a relatively brief space of time and the usual depths of about 70 to 100 metres (38 to 54 fathoms) will be reached in a fraction of a second. It is this rapidity of sounding by the acoustic method which formed its principal attraction from the beginning.

The sketch (fig. 1) gives an idea of the apparatus and of the propagation of the sound-waves.

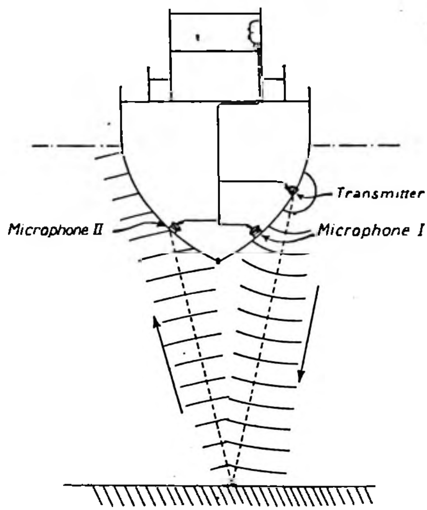


FIG. 1

In order to obtain a sounding, a submarine spherical wave or group of waves, is produced; the wave, following the path indicated on the figure, first of all acts on the departing receiver (microphone I), then, after being reflected by the bottom, the returning wave (or echo) acts on its return on the arrival receiver (microphone II). Microphone I starts the chronometer, Microphone II stops it.

The distance travelled by the wave is deduced from the interval of time thus measured taking the velocity of the sound wave through water to be constant and known at the time of the sounding. From the situation of the receivers on board, for instance, from the

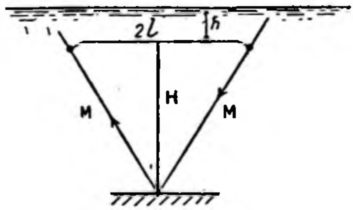


FIG. 2

distance between them 2l and from the known distance of immersion h (fig. 2) the total depth can be deduced from the formula :

$$\begin{cases} S = h + H = h + \sqrt{M^2 - l^2} \\ 2M = V \times t \end{cases}$$

$$S = h + \sqrt{\frac{1}{4} V^2t^2 - l^2}$$

Since the velocity of sound in water is in the vicinity of 1,500 metres per second, we have approximately :

$$S \text{ mètres} = h + \sqrt{560\ 000\ t^2 - l^2}$$

and, in order to measure a depth within 0.25 metres (10 ins.), an accuracy of 1/3 000th of a second in the measurement of t. is required.

A 3 inch echo occupies only...........	1/10,000th of a second.
A 1 foot echo occupies only..........	1/2,490th — —
A 1 fathom echo necessitates only.....	1/415th — —
A 5 fathoms echo necessitates only.....	1/83rd — —

The starting and stopping of the recorder must be accomplished in a lapse of time which is so short that it necessitates, on the one hand, the use of relays without delay action, and, on the other hand, excludes the employment of the non-continuous or alternating movements usually used in horometry.

The difficulty lies in the necessity of estimating, in order to obtain precise measurements (for instance of 1 and 2 metres), extremely short time intervals down to a thousandth part of a second!

Soundings at a depth of 5 metres, under the acoustic apparatuses, which necessitate the return of all the transmitting and receiving units to their initial position in less than 1/150th of a second, is somewhat difficult to obtain; further, an error of 1/1,000th of a second in determining the echo time involves an error of 0 m. 75 in the sounding.

We will see later on, when studying the different appliances, how skilful inventors have created very sensitive devices for measuring the time intervals, which have sometimes been called "chronomicrometers" or "steno-chronometers".

In principle, a sound generated on board ship under suitable conditions reaches the bottom of the sea at the nearest point and is then reflected as an echo: if the bottom of the sea is flat and horizontal, the nearest point will be situated under the vertical line of

the ship. and the echo distance, i.e. the number obtained by multiplying half the time which elapsed since the transmission of sound until the reception of the echo by the mean velocity of sound in sea water, will be equal to the sounding at that point.

Thus the measurement of the depth will be deduced on board ship, from the observation of the time interval t, called "echo time" which elapses between the emission of a sonic signal and the reception of the echo of the same signal reflected by the bottom of the sea, the latter acting as a mirror.

If the separation between the transmitter and the receiver is negligible, and if these two apparatuses are immersed at the same level, the depth below that level will be given by the formula $S = \frac{Vm\ t}{2}$, where the mean velocity of sound Vm between the surface and the bottom of the sea is assumed to be known.

III. Classification of Echo-Sounding Equipment.

As stated above, the frequency of the vibratory movement does not affect the velocity of the transmission of sound through water; but we shall study later on its influence on the absorption of elastic waves in water, that is to say, on the range of sounding attainable.

If the frequency remains between 50 and 18,000 periods approximately per second, the sound produced is audible, i.e. perceptible by the human ear. Above 18,000 periods per second, it becomes inaudible and the vibration produced is called ultra sound (super sound), and the corresponding waves are called ultra sonic (super sonic).

Consequently, the transmitting devices used in echo sounding can be classified in several categories according to the transmitting frequency used, that is to say according to the nature of the acoustic process employed.

a. *Sounding by means of detonations or blows*, utilising a violent noise, i.e. a very much damped powerful pressure wave, reduced nearly to one vibration, of very short duration, such as is produced by a rifle or the blow of a hammer on a non-resonant object: the echo is only distinguished by its intensity from the other parasitic noises which accompany a ship's course (in this category should be included the German and French solutions of sounding by means of detonations and the British, American and French solutions of sounding by means of a hammer blow).

b. *Sounding by means of audible frequency waves*, using a vibration either maintained at a frequency of the order of 1,000 oscillations per second, similar to the sound produced by a whistle or siren, or slightly damped, such as the sound of a bell or piano, the sinusoidal nature of the ondulating process being used in order to distinguish the echo from parasitic noises, by means of resonant devices. (American solution of sounding by means of oscillators).

c. *Sounding by means of inaudible frequency waves*, using in exactly the same way the ultra sounds or super sounds of a frequency of 30,000 to 50,000 vibrations per second, i.e. of too high a frequency to be perceived by the human ear (French solution of the properly so-called sounding by means of ultra sounds, and English solution of super-sonic sounding by means of magnetostriction, the latter using frequencies of the order of 16,000 vibrations per second).

All the above solutions are based on the direct determination of the time employed by a sonic wave to reach the bottom of the sea and to return to the surface after production of an echo. This interval is generally called "echo interval" and the apparatuses comprise a transmitter, a receiver and a control mechanism which also serves to measure the "echo interval" with all suitable accuracy. It is known, in fact, that an error of one second on this quantity would involve an error of about 750 mètres on the depth, and when it is desired, in coastal hydrographic surveys for instance, to obtain an accuracy of a few centimetres, it is easy to see that the precision to be obtained on the measurement of the time interval should be of the order of 1/10,000 of a second.

When received, the echo can be, according to the case, recorded either graphically or by means of earphones, or noted on a graduated scale using the deviation of a luminous spot or the lighting of an electric bulb.

The time interval between the transmission of sound and the return of the echo is generally measured by means of the angle produced either by a rotating arm, or a disc, or a luminous ray, the motion of which is regulated by a constant speed motor and produces a regular transmission of signals. Later on, several developments of these devices will be described.

IV. Physical Properties of Waves used in Echo-Sounding.

Absorption through water; Frequencies and theoretical ranges; Directional properties.

The vibrations of elastic mediums (solid, liquid or gaseous) produce, when they reach the human ear, the sensation of *noises*, when there is no periodicity in the vibratory movement, and the sensation of *sounds*, when there is periodicity, the simple sounds corresponding to sinusoidal vibrations. The most important characteristic of the sensitivity of a sound is the frequency N of its period, i.e. the number of double vibrations per second.

In slow vibrations below the frequency of approximately 16, the human ear perceives nothing; the "infra sounds", therefore, hardly have any practical application.

The range of the more usual sounds (human voice and musical instruments) extends from approximately 16 to 5,000 periods per second. Above that figure the ear still perceives more and more acute sounds similar to those of a whistle. Sensitive audition, hereafter, decreases and ceases in the vicinity of 15,000 to 20,000 vibrations per second, according to individuals.

Ultra sounds, inaudible to the human ear, then extend from frequencies of 15,000 or 20,000 up to the highest values: 100,000, 600,000 etc., but in reality there is no discontinuity, outside this threshold of human sensation, between the properties of audible acoustic vibrations, or sounds, and that of ultra sounds.

The use of Hertzian waves can hardly be taken into account for purposes of sounding, because their propagation through water, inversely to what takes place in the air, is very rapidly stopped, even more rapidly than that of luminous waves; it would, furthermore, be extremely difficult to discern their echo, and we must therefore limit ourselves to the use of elastic waves which are propagated through compression or dilatation of the medium they traverse.

The velocity of the propagation of elastic waves is given by the formula

$$V = \frac{1}{\sqrt{\mu . \rho}}$$

in which ρ is the density of the medium and μ the coefficient of adiabatic compressibility; these two coefficients vary slightly in accordance with the temperature and pressure.

In the air at 15 centigrades........	V = 340	m/sec.	approximately
In fresh water at 15 centigrades...	V = 1,440	—	—
In sea water at 33 °/°°...........	V = 1,500	—	—
In steel	V = 5,136	—	—
In quartz	V = 5,440	—	—

The absorption of elastic waves in water is nearly entirely due to viscosity; the loss of energy through calorific conductibility is, in fact, very small, owing to the slightness of the compressibility of water. The penetration modulus (i.e. the distance at which the amplitude of motion of the particles is reduced in the ratio 1 : e, (e being equal to 2,7183 : $\frac{1}{e}$ is therefore very close to $\frac{1}{3}$) is given by the following formula $\frac{3 \lambda^2 \rho V}{8 \pi^2 \eta}$ where η represents the coefficient of viscosity. The low frequency waves are therefore less absorbed than those of high frequency.

The frequencies N as used in salt water, are related with the wave lengths λ and this is shown by the well known formulae

$$\lambda = VT \text{ and } T = \frac{1}{N}$$

N = 1,000 periods per second, corresponds to 1,5 metre of wave length; (this is the frequency for which the human ear possesses maximum sensitivity).
N = 20,000 corresponds to 7 centimetres wave length ;
N = 40,000 — 3,5 — —
N = 100,000 — 1,5 — —

The musical sound a' (once accented) (N = 435), occupies in the water a wave length of 3,45 metres.

If we use the formula giving the absorption due to the viscosity in the case of water, we find :

$$\varepsilon = 2.\ 10^{7}\ \lambda^{2}$$

For the frequency 40,000, this absorption will occur after a distance of about 30 kilometres, and for the frequency 100,000, it will occur after 5 kilometres, which limits the use of too high frequencies. In the same way as in the air, acute sound components are absorbed far more rapidly than low components. However, with the same frequency, the absorption is 2,000 times smaller in water than in the air, that is to say that a much larger range can be attained in water. In the case of audible sonic waves, such as the sound of a powerful sub-marine bell, there is no noticeable absorption.

For instance, the use in water of plane waves of not too high frequency, of the order, for example, of 20,000 to 50,000, gives theoretical damping distances of some multiples of ten kilometres which are suitable to their practical use in sub-marine acoustics. In the air, on the contrary, ultra-sounds have a practical range of only some metres or multiples of ten metres, and this is the reason why there exist hardly any applications of this type of acoustic frequencies in the atmosphere.

The range of transmission of these elastic waves in water is far greater than that which we imagine when considering this transmission through air. The simple blow under water of a hammer on a block of steel gives a sufficiently powerful wave to reach a depth of several thousands of metres. The noise of the detonation of a cartridge containing only 100 grammes of explosive can be heard at a distance of several hundreds of kilometres, and the explosion of a charge of 1 kilogramme can set in vibration the whole of a large sea basin, such as the western Mediterranean, i.e. a liquid mass of 2 to 3 kilometres depth and about 800 kilometres breadth. Inversely to what happens in the air, where the optical range plays the principal role, acoustics possess an unlimited range through water, whereas the optical range does not exceed a few decametres.

Further, as the liquid mass of the oceans generally shows a considerable decrease in temperature as the depth increases, there results also a decrease in the velocity of sound and consequently a progressive dip towards the bottom, of the original vertical wave front, or, which is the same a downward curve of the "sonic rays", which is in every way similar to the well-known phenomenon of refraction of optical rays. On the other hand, the increase in pressure due to ocean depths entails an increase in velocity which would result in an upward curve of the sonic rays. These two phenomena can cancel each other by superimposing their contrary action, and the sonic rays are then propagated in a straight line.

This phenomenon of the curvature of sonic rays in a vertical plane has been called "sonic mirage" by analogy with the optical phenomenon which occurs in the propagation of luminous rays through the lower layers of the atmosphere.

When the sonic mirage occurs, there is generally the possibility of several acoustical tracks to join one point with another, and the time of propagation is not absolutely the same on these different tracks; thus, in 1924, during a trial on acoustical propagation between the coast of Provence and that of Algeria (a distance of about 800 kilometres, covered in 9 minutes by the noise of a detonation) a spreading of the sonic power, lasting 15 seconds, was noticed. When the downward curve of the sonic rays prevails, the latter hit obliquely the bottom of the sea where they are reflected and return to the liquid body with the same incidence. These frequent reflections on the bottom of the sea diminish the acoustical power, and this fact, added to the above-mentioned spreading, sometimes considerably reduces the range of sub-marine noises on a horizontal plane.

Assuming that the source of sound transmitted in the elastic medium is a point, for instance by assuming the source as constituted by a small pulsating sphere, propagation

would occur equally in all directions around the point; the waves produced are spherical, there is no privileged direction : this is the case for the siren of a ship emitting for instance the note small c, of a frequency of 130, of a wave length of 2,6 metres in the air, and which is heard equally in all directions.

If the sonic source is constituted by a small vibrating piston, of which the diameter d is small by relation to the wave length λ of the emitted vibration (fig. 3) the transmission is also spherical.

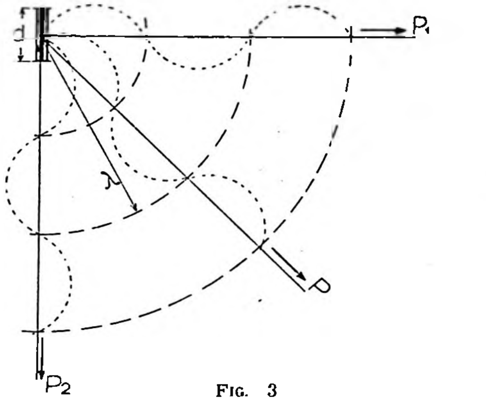


FIG. 3

By applying the Huyghens principle, i.e. in considering each point of the piston as parts of very small synchronous sources, the resulting amplitude of the sound at a remote point P will be the sum of the amplitudes due to each elementary point source. There would be silence at this point if these vibrations reached it with phase lags of a half wave length. However, the greatest difference of track occurs for point P_2 in the plane of the piston and is equal to d. If d is very small compared with λ, even at point P_2 which is the most disadvantageous, the vibrations of all the parts arrive with very small phase lags. At P_1, on the line of the axis, the phases are concordant, and consequently, in the present case, the resulting sound has a practically constant amplitude in all the vibratory field of the piston.

If the lateral transmission d of the source is large as compared with the wave length λ, the various sonic tracks joining a remote point P to the elementary sources (fig. 4), can present among themselves differences of tracks equal to $\frac{\lambda}{2}$. Odd multiples of

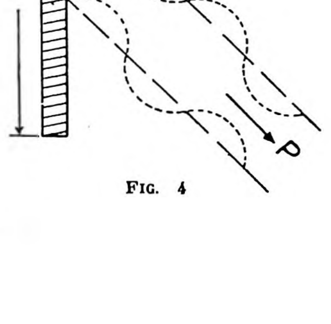


FIG. 4

$\frac{\lambda}{2}$ are obtained, the resulting vibrations interfere and consequently in certain points of the field, vibrations emanating from various zones of the source can cancel each other.

Calculations show that the sonic field at great distance is the cone of revolution around the perpendicular of the face of the piston, or vibrating plate of a transmitting oscillator, with a very pronounced central maximum and small lateral maxima separated by cones of silence.

Figure 5 shows the distribution of emitted energy in a section perpendicular to the axis.

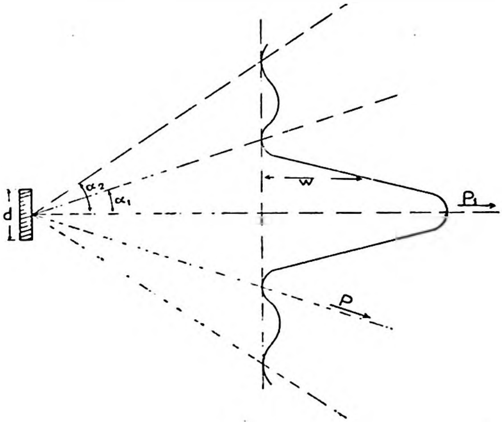


FIG. 5

The emission is obtained with the maximum intensity in the normal direction of the vibrating plate. The apex angles of the cones of silence are given by the following formulae :

$$\sin \alpha_1 = 1{,}2 \frac{\lambda}{d}, \ \sin \alpha_2 = 2{,}2 \frac{\lambda}{d}, \text{ etc.}$$

The secondary maxima being very small, the 9/10ths of the vibrating energy for such a transmitter are contained inside the first central cone of apex 2α and thus the transmission assumes "directional" properties. (*)

This apex angle of the opening of the beam should be, under normal conditions, of about ten degrees, which provides a certain relation between the wave length and the diameter of the source. As the latter should be limited to moderate dimensions for use on board ship, such as 20 centimetres for instance, the following condition $\lambda < 3{,}5$ centimetres holds good, corresponding to about 40,000 periods, that is to say ultra-sonic waves which, besides this directional property, present the advantage of being inaudible and thereby ensuring secrecy.

(*) See a more detailed account in *Hydrographic Review*, Vol. II, N° 1, November 1924, pages 57 & sq. "The employment of ultra-sonic waves for echo-sounding".

V. Selection of Velocity of Sound to be used in Echo-Sounding.

It has been stated above that the accuracy of acoustic sounding is determined partly by the accuracy with which the velocity of travel of sound in salt water is known.

During the last few years, much new research and many experiments in direct measurement through open water have been carried out by various nations. They were made in connection with various problems of submarine ranging in order to determine more exactly the velocity of propagation of sound waves through sea-water. We will cite only a few of the more recent ones in the Bibliography at the end of this chapter.

The horizontal velocity of sound in sea water varies with the temperature of the water, its salinity and the pressure, that is to say with the depth. The theoretical formula $V = \frac{1}{\sqrt{\mu\rho}}$ from which is deduced: $\frac{dV}{V} = -\frac{1}{2}\left(\frac{d\mu}{\mu} + \frac{d\rho}{\rho}\right)$ permits the separate influence of each one of the above factors to be analysed (salinity, temperature, depth) both on the density ρ and on the coefficient of adiabatic compressibility.

Briefly, the velocity of the vertical transmission of sound through sea water used for sounding, depends on the temperature, the salinity (or the density) and the pressure of the various layers of water crossed. Under average conditions it remains in the vicinity of 1.500 metres or 820 fathoms per second; the extreme values can exceptionally differ by 60 metres per second either more or less. In general, it can be said that the velocity increases by 2,3 metres per second when the temperature increases by 1° C.; by 1 metre per second when the salinity increases by 1 per 1,000 and by 1 m. 50 per second for an increase of pressure of 10 atmospheres, i.e. approximately every 100 metres of depth.

Rigorous acoustic sounding would require, theoretically, a knowledge of the series of temperatures and salinities of the various layers of liquid traversed by the sound, at the point and at the time when the echo interval is determined.

Direct measurement of velocity "in situ" being a difficult operation, preference is given to the indirect calculation based, on the one hand, by taking into account certain properties of the water as determined in laboratory experiments and, on the other hand, by deducting the temperature and salinity of the various layers through basic observations carried out at stations suitably selected in the area concerned.

It is further admitted that in their track between the surface and the bottom, the transmitted waves cross the superimposed horizontal layers of water of equal thickness, for each one of which it is assumed that the temperature and salinity are known, as well as the pressure according to depth.

Consequently it is necessary to calculate the mean horizontal speed in each layer between the surface and the given depth. The mean of these averages constitutes the mean vertical velocity which is selected for the soundings in question, or "sounding velocity" V_m, by which the duration of the single track must be multiplied in order to obtain the depth.

This calculation of V_m is rather intricate and is based on the selection of various physical considerations, subject, further, to certain variations. Finally a tabulation is drawn up of the velocities to be used.

The tables in general use are either those of the U.S. Coast and Geodetic Survey, Special Publication N° 108, by N.H. Heck and J.H. Service, Washington (1934) (*), or those of the Hydrographic Department of the British Admiralty, Publication N° H.D. 282 by D.J. Matthews, London, 1927. The latter are based on the following considerations :

(*) These American tables are partly described and reproduced with the article entitled "Velocity of transmission of sound in sea water" published in *Hyd. Review*, Vol. III, N° 1, Monaco, Nov. 1926, p. 69 to 96 and Vol. IV, N° 1, May 1927, page 220.

The Velocity of sound in each layer is shown in the expression

$$V = \sqrt{\frac{dp}{d\rho}} \text{ or } V = \sqrt{\frac{\gamma}{\rho k}}$$

in which ρ is the density or specific weight, k the true compressibility $-\frac{1}{v}\frac{dv}{dp}$, v being the volume, and γ the ratio of specific heats with constant pressure and constant volume C_p and C_v. The introduction of this ratio is due to the adiabatic process of propagation. The specific heat of sea water under constant pressure C_p which is expressed in calories per gramme and per centigrade degree, has been determined by Thoulet and Chevallier. It is assumed that it varies according to the temperature in the same way as pure water. It decreases very rapidly when the pressure increases. C_v, specific heat with a constant volume, is equal to $C_p - \frac{T\alpha^2}{\rho k J}$, in which T is the absolute temperature, α the coefficient of thermal dilatation, as determined by Ekman and Knudsen, and J the mechanical equivalent of heat.

On the other hand, $\rho = \frac{\rho_o}{1 - p\mu}$. In the latter expression, ρ_o is the density with the atmospheric pressure, as calculated from the salinity by means of Knudsen's hydrographic tables; p is the pressure expressed in bars and μ the *mean compressibility*. The latter has been defined and determined by Ekman, who gave its value in terms of the pressure, the temperature and the density at 0°. The true compressibility is calculated according to the expression :

$$k = -\frac{1}{v}\frac{dv}{dp} \quad \text{or} \quad k = \frac{\mu + p\frac{d\mu}{dp}}{1 - p\mu} \cdot 10^{-6}$$

In the two above formulae, the pressure can be numerically expressed in terms of depth by using the Ekman tables. The pressure at a given point depends on the depth, on the density of the upper layers and on the value of gravity, the latter varying also with the latitude but this variation entails discrepancies of only a few decimetres on the velocity of the sound.

With the tables of the Hydrographic Department, it is possible to calculate the mean velocities of sound; they provide, moreover, for the usual purposes of navigation, approximate values of these speeds in the shape of 23 very condensed tabulations, drawn up for 23 "isophone" areas which cover the whole surface of the oceans and in each of which the average temperature of the water layers can be considered as nearly the same at the same depth. (The salinity has been taken into account only for the Mediterranean and Red Sea regions). Thus the mariner can obtain at a glance a value sufficiently approximate to the mean velocity of sound according to depth, in the area where he is situated, in accordance with the geographical position of the ship.

In the absence of a larger number of direct control measurements, it is difficult to come to any very definite conclusion as to the accuracy of these tables, but it seems probable that they are reliable to two metres per second at temperatures up to about 22° C., in water such as normally occurs in the open sea, and at depths not greater than 2,000 fathoms or 4 000 metres, and that the accuracy is much greater in shallow water.

The following data, for example, show the error in a sounding as a function of the depth, and of an error in estimation of the velocity of sound.

Depth in metres	ERROR IN VELOCITY OF SOUND in metres per second							
	2	10	15	20	25	30	35	40
1,000........	3	7	10	13	17	20	23	27
2,000........	7	13	20	27	33	40	47	53
3,000........	10	20	30	40	50	60	70	80
4,000........	13	27	40	53	67	80	93	107
5,000........	17	33	50	67	83	100	117	133
6,000........	20	40	60	80	100	120	140	160
7,000........	23	47	70	93	117	140	163	186
8,000........	27	53	80	107	142	160	187	222

Variations between theoretical values calculated for speed and those derived from direct measurements can be explained by the presence of gas in sea water.

In practice, physical conditions met with at sea are such that mean velocities to be used differ only slightly from a same value (1,500 metres/sec. or 820 fathoms/sec. for example), and, as the temperature of water generally decreases with depth, the increase in speed involved by the increase of pressure is somewhat compensated by the decrease of speed entailed by the decrease in temperature; this fact, however, only occurs down to a certain depth of the ocean. Beyond that depth the temperature remains practically the same down to the abyssal depth, the influence then of the increase in pressure becomes preponderant and produces an increase in velocity.

Moreover, we must draw attention here to several studies effected by various countries to improve our knowledge of mean velocities to be used in certain localities, for instance: the experiments effected in November/December 1923 by the United States Coast and Geodetic Survey ship *Guide* for measuring vertical velocities in the Nares Deep.

An extrapolation for the great depths by Dr. H. Maurer in 1927/29 of the Tables H.D. 282 of the Hydrographic Department, London, made during the cruises of the German ships *Emden*, *Berlin* and *Meteor*. This was published as an appendix to Nachrichten für Seefahrer N° 10, Berlin, 1930, and the tabulation was reproduced in the *International Hydrographic Bulletin* N° III, March 1932, page 54.

In 1929, Asaiti Muramoto, hydrographic engineer, taking as a basis the oceanographic data collated by the surveying vessel *Mansyu* in the seas in the neighbourhood of Japan, calculated the velocities to be used in these said seas for echo-sounding: these velocities are given in the *International Hydrographic Bulletin*, N° V, Monaco, May 1929, page 119. A theoretical account concerning the calculation of velocity to be employed in echo-sounding, by Naval Engineer Susumu Kuwahara, was given in the *Hydrographic Bulletin* (Suiro Yoho) October/ December 1937, published by the Japanese Hydrographic Department.

Further, a supplement to tables H.D. 282 covering the region of the Dutch Indies, was drawn up by the Netherlands Geodetical Commission, and is indicated in the *International Hydrographic Bulletin*, 1935, N° 11, page 36.

Utilising the oceanographic measurements taken by the *Carnegie*, the United States Coast and Geodetic Survey published constant regional correction factors covering 14 zones of the Pacific Ocean; these were reproduced in the *Hydrographic Review*, Vol. XII, N° 2, Monaco, November 1935, page 95.

Further, seasonal variations in the temperature and salinity of the upper layers of the Ocean, reaching up to 10° C., were noticed by the *Carnegie* during her cruises in the Pacific Ocean. It can be assumed that such seasonal variations are noticeable down to a depth of approximately 500 metres, which would involve errors in the vicinity of 0.2 % on the velocity of sound for a depth of 2 500 metres and of 2 metres approximately per second for a depth of 4,000 metres. (See *Hydrographic Review*, Vol. XII, N° 1, page 167).

Various empirical formulae have been given to express the velocity of sound in sea water in terms of temperature and salinity for the upper layers where pressure does not yet exert a marked influence. A study of these formulae and the diagrams derived therefrom are given in the *Hydrographic Review*, Vol. II, N° 2, May 1925, pages 186-189. We would cite, for example, the formula estbalished by Dr. H. Maurer and which agrees in a general way with the data of the British tabulation H.D. 282.

$$V \text{ metre/Sec.} = 1445.5 + 4.62\,t - 0.0452\,t^2 + (1.32 - 0.007\,t)\,(S - 35)$$

in which t is the centigrade temperature and S the salinity per thousand. (See *International Hydrographic Bulletin*, 1930, N° IV, page 72).

Interesting information is given in the *Hydrographic Review*, Vol. XII, N° 2, Nov. 1935, page 81, concerning the acoustic work effected recently by the United States Coast and Geodetic Survey in order to determine the horizontal velocity of horizontal propagation of sound in sea water, in connection with radio-acoustic ranging and its more and more extensive use for hydrographic operations offshore. This subject is also dealt with in the *Hydrographic Review*, Vol. XIV, N° 2, November 1937, pages 93 to 153, in an article by Commander O.W. Swainson, entitled "Velocity and Ray Paths of Sound Waves in Sea Water".

BIBLIOGRAPHIC REFERENCES

concerning the velocity of sound in sea water,

1890. R. THIELFALL & J.F. ADAIR. — Velocity of transmission through sea water of Disturbances of large amplitude caused by Explosions, Experience made in Sydney, Australia in 1888. - Proc. Royal Soc. London, Vol. 46, 1890, pp. 496-541.

1919. Ing. Hyd. P. MARTI. — Note sur la vitesse de propagation du son dans l'eau de mer. - Annales Hydrographiques, Paris, 1919.

1919. H. BRILLIE. — Etude des ondes acoustiques. - Le Génie Civil, Paris, 1919, Vol. 75, pp. 171, 194 et 218.

1922. Dr. F. AIGNER. — Unterwasserschalltechnik, p. 46. - M. Krayn, Berlin 1922.

1923. A.B. WOOD & Capt. Harold BROWNE. — Rapport N° 79 au XIII° Congrès International de Navigation. - Admiralty Department of Scientific Research, London, 1923, et Proceedings Royal Society, A. 103, page 284, London, 1923.

1923. E.B. STEPHENSON. — Velocity of Sound in Sea Water. - Physical Review, Vol. 21, Feb. 1923, pp. 182-185.

1924. Cdr N.H. HECK & J.H. SERVICE. — Velocity of Sound in Sea Water (with Tables). - U. S. Coast and Geodetic Survey, Special Publication N° 108, Washington, 1924.

1924. H. MAURER. — Über Echolotungen der Nordamerikanischen Marine. - Annalen der Hydrographie, Berlin, Avril 1924, pp. 75-87.

1925. A. SCHUMACHER. — Hydrographische Bemerkungen und Hilfsmittel zur Akustischen Tiefenmessung. - Annalen der Hydrographie, Berlin, Avril 1924, pp. 87-95.

1924. H. MAURER. — Das Englische Echolot. - Annalen der Hydrographie, Berlin, September 1924, p. 221, et Mars 1930, p. 104.

1927. D.J. MATTHEWS. — Tables of the Velocity of Sound in pure Water and Sea Water for use in echo sounding and sound ranging. - Publication H.D. 282, Hydrographic Department, Admiralty, London.

1928. Ing. Hyd. Principal MARTI. — Expérience de propagation d'onde sonore sous-marine, effectuée en 1925 par la Marine Française à travers la Méditerranée. - Rapports et Procès-Verbaux. Commission Internationale pour l'Exploration Scientifique de la Méditerranée, Vol. III, Paris, Mai 1928, p. 31.

1929. E. LUBKE. — Vitesse du son dans l'eau de mer. Zeitschrift für technische Physik, 1929, N° 9, p. 386.

1930. R.W. KNOX. — Experiments made by the U.S. Coast and Geodetic Survey on the Coast of Northern California, 1929. - Bulletin of Field Engineers, Washington, June 1930.

1930. Gustav ELFVING. — Zur Reduktion von Echolotungen. - Havsforskningsinstitutets Skrift N° 69, Helsinki, 1930.

1931. G.D. COWIE & T.B. REED. — Determination of velocity of sound in sea water in Cape Cod Bay. Bulletin of Field Engineers, Washington, N° 4, December 1931, p. 88.

1933. H. MAURER. — Die Echolotungen des *Meteor*, Wissenschaftliche Ergebnisse der Deutschen Atlantischen Expedition 1925-27. - Band II text page 26, Berlin, 1933.

1934. P.A. SMITH. — Recent Acoustic Work of the U.S. Coast and Geodetic Survey. - Bulletin of Field Engineers N° 8, Washington, Dec. 1934, pp. 60-75.

1935. F. PINKE. — Velocity of Sound in Sea Water. - Netherlands Indian Archipelago and Sulu Sea. - Appendix N° 1. - The Snellius Expedition 1929-1930, Vol. II, Part 2, Chap. 1. Depth Determinations, Leiden 1935.

1937. O.W. SWAINSON. — Velocity and Ray Paths of Sound Waves in Sea Water. - Revue Hydrographique, Vol. XIV, N° 2, November 1937, pp. 97-160.

1938. Susumu KUWAHARA. — Velocity of Sound in Sea Water and calculation of the velocity for use in sonic sounding. - Extrait du Suiro Yoho N° 10-12 de 1937, Hydrographic Department, Tokyo, 1938.

VI. Sources of Errors and Correction of Echo-Sounding.

Echo-sounding apparatuses give the measurement of what we have called "echo interval" t. However, their scales are not graduated in seconds of time but directly in depths $h = \frac{V_a \times t}{2}$, according to a certain calibration speed V_a selected by the makers, and in accordance with which the *constant speed* of the motor is determined.

In general, the value of this constant calibration speed is indicated on the apparatus, and varies with the different makers, but it is generally selected on the basis of the mean value 1,490 metres/sec. (800 fathoms or 1,463 m/sec.; 815 fathoms = 4.890 feet) or 1,500 metres/sec. (820 fathoms = 4.920 feet). Furthermore, the zero of the measuring scale must correspond exactly with the zero of time measurement of soundings, in order that no lag is produced causing a zero error, and more particularly the zero of the scale must be in accordance with the value of the draught generally common to the transmission diaphragm and to the echo-receiving microphone.

In any other case, it is necessary to make the following corrections on echo soundings:

1° Correction relative to the *draught* of microphones: the latter being nearly a constant determined once for all at the time the apparatus is fitted on board.

2° A correction for the *separation* which exists sometimes between the transmitter and the receiver when they are distinct one from the other. This is an unfavourable condition when sounding in shallow water. The formula which we have given on page takes this separation into account. However, the installation on board is effected in such a way that, when necessary, the separation between the transmitter and the receiver is very small, and for shallow water the necessary correction of the scale is calculated to allow for this separation.

3° Correction of *sound velocity* due to the fact that the calibration velocity does not correspond exactly with the actual value of mean velocity "in situ" V_m, the only one suited to the application of the formula.

This correction is deduced from a simple calculation based on the known calibration velocity V_a and the velocity V_m deduced, for instance, from Tables H.D. 282 of the British Admiralty: it corresponds to $(V_m - V_a)\frac{t}{2}$ and, by designating by h_a the depth furnished directly by the apparatus, the correction to be made when reading h_a is as follows:

$$\frac{h_a}{V_a}(V_m - V_a)$$

In a general way, this correction is considered negligible for depths of less than 200 metres.

4° A so-called *slope correction* is rendered necessary by the fact that the echo interval, as recorded by the apparatus, corresponds, when the surface of the bottom of the sea is not a horizontal plane, to the smallest distance ED between the transmitter and this surface, and not to the true depth EH (fig. 6).

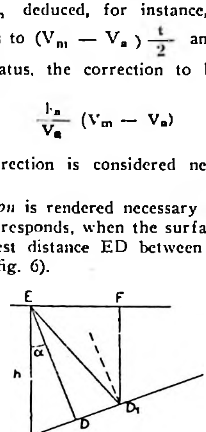


FIG. 6

However, a distinction must be made here between quartz and acoustic sounders. The former have the property of producing a directional ultra-sonic beam, whilst the latter transmit waves which are propagated in every direction around the transmitter.

In the first type of apparatus, it may be assumed, although this conclusion is not definitely adopted, that the apparatus gives the depth reckoned along the vertical of the projector, and that, therefore, it is not necessary to effect a slope correction.

The case is not the same, however, when the transmitter produces ordinary sound waves, or even when a magneto-striction transmitter is used, for which the diameter of the source is of the order of the wave length (0 m. 10).

Several methods have been proposed for the calculation of this slope correction. Mr. Marti, in particular, has shown (see *Hydrographic Review*, Vol. X, N° 2, November 1933, page 172) that it is easy to determine the latter and to obtain at the same time the slope of the bottom in cases where multiple echoes have been recorded following a single sounding.

The first echo corresponding to the sonic track EDE, HDE being a right angle, the second echo corresponds to the track ED_1 FD_1 E (fig. 6). The depth is then obtained by the formula :

$$H = \Delta + \frac{\Delta - \Delta'}{2}$$

in which Δ is the depth as shown on the recorder by the peak of the first echo and Δ' is the length corresponding to the interval between this peak and that produced by the second echo. The slope of the bottom is expressed by $\tan \alpha = \sqrt{\frac{\Delta - \Delta'}{2}}$ This method of reasoning assumes that the slope of the bottom remains constant between points H and D_1. (See *Hydrographic Review*, Vol. X, N° 2, November 1933, page 172).

In the much more common case, where no multiple echoes are recorded, various correction methods may be used such as the one explained by Dr. H. Maurer in the *Annalen der Hydr. und Mar. Meteor.* Sept.-Oct. 1926, or the reduction diagram of the Coast and Geodetic Survey explained in the *Hydrographic Review*, Vol. V, N° 1, May 1928, page 163 (See also A.L. Shalowitz, *Hydrographic Review*, Vol. VII, N° 1, May 1930, pages 82-98).

However, the more general and more rational method seems to be that advocated by Ingénieur hydrographe général P. de Vanssay de Blavous, in *Hydrographic Review*, Vol. VII, N° 2, November 1930, page 50; Vol. X, N° 1, May 1933, pages 38 and 41; Vol. X, N° 2, November 1933, page 180 and *International Hydrographic Bulletin*, 1933, N° 7, page 122, by means of diagrams.

Briefly speaking, this method is as follows : first, a provisional plotting sheet of soundings is established on which all the echo distances obtained by the sonic sounder are inscribed, without making any slope correction. On this plotting sheet, depth curves are drawn at a suitable equidistance. Each sounding plotted is then shifted normally to the surrounding depth curves, towards the lesser depths and by an amount equal to the sounding multiplied by the slope p of the surface as represented by the projection inscribed on the provisional plotting sheet, the slope being deduced from the distance separating the depth curves in the vicinity of the sounding in question. At the point thus obtained which is but the representation of point D of the preceding figure, the product of the provisional sounding by the factor $\sqrt{1 - p^2}$ is written.

The above rules are obtained by observing that the true surface of the bottom is the envelope of the spheres described from each of the points of the surface of the sea corresponding to each sounding on the provisional plotting sheet, with a radius equal to that sounding.

A geometrical study of the question shows that sonic soundings can give but an imperfect representation of the steep depressions which are sometimes met with in the oceans, as echoes may only be received from the sides of the depression and not from the deepest

part. (fig. 7). In this case, it may be necessary to have recourse to wire soundings. On the other hand, the acoustic process is well fitted for determining the relief of sub-marine hills, and, consequently, to the detection of shoals and wrecks.

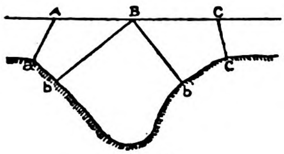


FIG. 7

5° A correction would be necessitated by *an error on the constant speed* of the motor, but it is assumed that in this connection variations would not exceed 1.5 %, unless the apparatus was damaged.

6° Lastly, a correction is necessitated by *the state of the tide;* this correction which is important in the case of shallow water, does not much affect measurements for great depths; it is, furthermore, inherent to the usual corrections made in coastal hydrographic soundings, whatever may be their nature.

VII. Use of Echo-Sounding.

Echo-sounding apparatuses provide "rough echo distances" which appear either in the form of *single soundings* obtained by the direct reading of the scale and which are recorded in the sounding book, or in the form of *graphic records*, a sort of profile of the sub-marine bottom drawn by the recording apparatus.

In every case, the above results must be intimately related, with all possible accuracy to the data giving the exact position of the ship at certain moments during the process of sounding and from which will be deduced the actual location of each sounding or of those soundings which will be selected from the recorded series.

We will not enter again here into the degree of accuracy with which this deduction can be effected, deduction on which depends the exactness of the position of the soundings which are to be utilised. Whilst this determination is sufficiently accurate for positions in sight of land, it becomes more uncertain beyond the limits of visibility of land marks or beyond the range limit of sound ranging apparatuses moored offshore. For oceanic soundings offshore, the precision of the location of soundings is governed by the error of the ship's position, and generally speaking, the uncertainty of the location of soundings in the high sea varies between 1 and 4 nautical miles, according to circumstances. The importance of this error explains the relative sense which must be attached to the topographic interpretation of soundings in the high sea, either in the case of single soundings, of series of parallel line soundings or of intersecting series, taken either nearly at the same time, or separated by long time intervals.

The final purpose being the inscription of soundings on the chart, it is impossible, owing to the relatively reduced scale of the latter, to utilise all the data furnished graphically by the recording apparatuses. For instance, with a recording apparatus operating at a cadence of 60 soundings per minute, the actual spacing between two successive soundings on the bottom is only 5 metres, when the ship's speed is 10 knots.

Moreover, owing to the scale of the graphical record, the measurement of the abscissae, i.e. the actual position of the sounding, can only be approximate when transferred from the graphic record to the plotting sheet.

For instance, with an echo sounder working at a cadence of 20 soundings per minute and with a recording strip unrolling at a speed of 90 centimetres per hour, the spacing between two successive soundings on the graph would be 9/12ths of a millimetre and would correspond to an actual spacing of 15 metres on the bottom. At any rate, a selection is, essential among the various ordinates recorded, selection which will be governed by the aim of the cartographer and by the details of the sub-marine topography which it is desired to emphasize.

The rational use of the enormous quantity of material collated by echo sounding, the nature itself of "rough echo distances", the question of correcting these echo distances and inscribing them suitably on charts, geophysical and other maps, has induced the Hydrographic Departments and the International Hydrographic Bureau to consider the adoption of certain common rules for their treatment.

Already in 1928, following the extensive exploration by the *Meteor* of the Atlantic Ocean by means of echo soundings, and in connection with the inscription of the results thereof on plotting sheets, the following questions were examined :

1° Whether the rough echo distances, as furnished by the apparatus, or whether the corrected soundings taking into account the local velocity of sound and, if necessary, of the slope, should be inscribed on the chart.

2° Whether the correction of soundings should be limited to those below 200 or 300 metres, as taken in general on the continental shelf.

3° Whether, on the charts, echo soundings should be distinguished by a special figure from wire soundings.

4° Whether it was suitable to select a mean standard and empirical velocity of sound for all the Oceans, to which would be referred all the echo distances, for instance 1,490 metres sec. This would entail a discrepancy with the true depths, which on an average would not exceed ± 3 % for flat bottoms, except in the case of the Red Sea where the discrepancy reaches 4.2 %. (See *International Hydrographic Bulletin*, 1928, N° II, page 29; N° IV, page 84).

5° The systematic grouping of oceanic soundings obtained by sound and the collating thereof by means of a standard formula of records (*International Hydrographic Bulletin*. N° VII, 1928, page 166), and if necessary the publication of same.

6° Keeping up-to-date, in accordance with the progress of science, a General Bathymetric Chart of the Oceans, which work had been undertaken in 1903 by H.S.H. the Prince of Monaco.

7° The expediency of collating new oceanic soundings in hitherto unexplored regions.

These various problems were discussed during the International Hydrographic Conferences held in Monaco in 1929 and 1932. (See the detailed Report of the meetings of the Third International Hydrographic Conference, April 1932, pages 93 to 102). In the *Hydrographic Review*, Vol. XIV, N° 1, May 1937, pages 71 to 95 an account is given, on the occasion of the Fourth International Hydrographic Conference, 1937, of the systems adopted by various countries with regard to plotting echo soundings on the chart, to their treatment and publication, and to the calibration of echo soundings.

The following decisions in connection with the above questions were adopted by the Conferences :

1° & 2°) Echo distances will be transformed as well as possible into depths and then be inserted on the charts in the same type of figures as that used for wire soundings.

Soundings obtained by echo should be plotted on the charts after having been corrected as much as possible.

3°) They should not be distinguished from other soundings marked on the chart.

4°) The scales of the echo-sounding appliances should permit either rough echo-distances or echo-intervals to be read. The signification of the scale shall be indicated on the apparatus itself (for a scale of length, the velocity on which it is based; for a scale of echo intervals, the unit of time involved).

No standard velocity for propagation of sound through sea water was adopted.

5°) *Centralisation of Oceanic Soundings :* The various Hydrographic Offices should invite the merchant vessels of their respective flags which are fitted with echo-sounding apparatus, to forward to the International Hydrographic Bureau the required information in the manner requested by the Bureau on its *model forms*.

Publication of Lists of Oceanic Soundings : I. — When publishing echo-soundings the following information shall be given :

The sounding vessel; the type of echo-sounding apparatus; the position of the sounding by longitude and latitude; the rough echo-distance; the calibration of the instrument and, if possible the local velocity of sound and the echo-distance corrected for this velocity.

All other possible corrections (e.g.: for slope) should be given separately. It is desirable to have data concerning the accuracy of the position obtained for the sounding and as to the source of the local velocity of sound used.

II. Hydrographic Offices receiving reports of oceanic soundings taken outside the continental shelf should (if they do not issue charts thereof on a sufficiently large scale) communicate them to the International Hydrographic Bureau in the form of Lists of Oceanic Soundings, giving positions by latitude and longitude, subdividing them by oceans and classifying them in this way.

MODEL FORM :

SOUNDINGS TAKEN OUTSIDE THE CONTINENTAL SHELF.

(International Hydrographic Bureau, Form N° 2 H-86)

Name of Vessel : .... **Apparatus used :** ....

Nationality : .... **Velocity of sound used as the basis in Echo-Sounding apparatus :** ....

Sailing from : .... **to :** ....

NOTE : — Should the echo-sounding apparatus be provided with a means by which the velocity of sound on which the scale is based can be varied, the velocity employed should be entered if it is not that stated above.

It is requested that, in the case of Echo Soundings, the method of correction applied, and particularly the local velocity of sound chosen for correction or the local Velocity Tables used, be indicated in the Remarks column

It would be well to indicate the accuracy with which the position of a sounding is fixed and actually observed positions should be specially marked in order to distinguish them from dead-reckoning position.

Additional data which it has been possible to obtain, such as : — the nature of the bottom, the temperature of the sea, its salinity and density, both at the surface and at the various depths, together with information as to how they were obtained (the units employed should be stated) should be inserted in the « Remarks » column. The state of the sea should be noted also in the case of wire soundings.

DATE	POSITION		DEPTH by Apparatus	Correction	Corrected DEPTH	REMARKS
	LAT.	LONG.				

Signature : .... ***Date :*** ....

This form, when completed, should be sent to the Hydrographic Office of your country for transmission to the International Hydrographic Bureau, Quai de Plaisance, Monaco.

The International Hydrographic Bureau, if necessary, shall publish the reports thus received in the *Hydrographic Bulletin*.

6° *General Bathymetric Chart of the Oceans* - (Keeping up to date). The International Hydrographic Bureau is made responsible for keeping the present chart up to date without changing the sections, projections or scale.

The International Hydrographic Bureau should make every endeavour to ensure that the representation of the depths should be as clear as possible.

The International Hydrographic Bureau is invited to attach to each edition of the sheets a small pamphlet giving the bibliography used as reference and the scientific expeditions, the itineraries of which had been used, and all other useful information.

7°) *Systematic study of unexplored Ocean areas* — It is recommended that each National Hydrographic Office indicate to the International Hydrographic Bureau in which ocean area it would be prepared to undertake work in the near future, the Bureau to centralise this information with a view to discussing international co-operation and co-ordinating the work which has been done by the various countries.

VIII. Practical Development : Former and Recent Devices.

In the following enumeration we will mention some former apparatuses now fallen into disuse, owing to the progress achieved by the makers, and in most cases we will refer the reader to the detailed descriptions given at the time in the various volumes of the *Hydrographic Review*.

With regard to recent apparatuses, we will only describe the new ones based on the pamphlets received from the makers and on the information given by the various Hydrographic Offices.

After the name of each apparatus and the approximate date when it was put into service, we will mention the number of the volume of the *Hydrographic Review* in which can be found a full description thereof.

Fessenden Depth-Sounder with Oscillator (1914).

Hydrographic Review, Vol. II, N° 1, November 1924, p. 93.

Navy Sonic Depth Finder of Dr. Harvey C. Hayes of the Engineering Experiment Station of Annapolis (1918-1922) *type S.E.* 1378.

Sounds from 40 to 500 fathoms, and soundings to depth of 5 to 75 fathoms can be obtained by the angular method.

Hydrographic Review, Vol. II, N° 1, November 1924, p. 112.
— Vol. II, N° 2, May 1925, p. 144.

Anschütz Behm Echolot of the Behm Echolot Gesellschaft of Kiel (1921) *with chronometer and photographic record.*

The Behm sounder Type II sounds from 8 to 410 fathoms.

Hydrographic Review, Vol. II, N° 2, May 1925, page 155.
— Vol. V, N° 2, Nov. 1928, page 133.
— Vol. VI, N° 2, Nov. 1929, page 163.

Signallot or Tiefsee Echolot of the Signal Gesellschaft of Kiel.

High speed: 1 sounding every 1 36 second down to 547 fms.
Low speed: 1 sounding every 12.3 seconds down to 4.920 fathoms.
Below 50 metres and down to the greatest depths, sounds at ± 5 fms.

Hydrographic Review, Vol. V, N° 1, May 1928, page 161.

Apparatus of the Department of Scientific Research of the British Admiralty (1922).

British Admiralty Echo Sounder, 1922.
Normal soundings from 8 fathoms 3/4 to 35 fathoms; deeper soundings with earphones.

Hydrographic Review, Vol. II, N° 2, May 1925, page 138.
— Vol. III, N° 2, July 1926, page 99.

Marti Recording Oscillograph (1922).

Large Model (hydrography): Radius 225 m/m - sounds from 0 to 109 fathoms, 1 sounding every 3 seconds, speed of the pen 3 metres per second.
Small Model: radius 180 m/m - sounds from 0 to 109 fathoms - 1 sounding every 5 seconds.

Hydrographic Review, Vol. II, N° 2, May 1925, page 141.
— Vol. III, N° 2, July 1926, page 89.

Ultra-Sonic Sounding Machine Langevin-Chilowsky of the Société de Condensation et d'Applications Mécaniques (1923)
with optical analyser system Langevin-Florisson:

1 sounding per second; sounds from 2 to 205 fathoms, or to 274 fathoms accord-

ing to the type of analyser, that is to say the limit in the graduation of the analyser's scale.

Hydrographic Review, Vol. III, N° 2, July 1926, page 75.
— Vol. V, N° 2, Nov. 1928, page 107.

with Echometer, model for small ships :

Sounds from 16 fathoms to 361 fathoms in general ; soundings are taken every 7/6th of a second.

Hydrographic Review, Vol. VII, N° 2, Nov. 1930, p. 105.
— Vol. X, N° 2, Nov. 1933, p. 168.
— Vol. XI, N° 2, Nov. 1934, p. 58.

(These descriptions correspond to the Marconi Echometers, type 421 or 430). See also :

Hydrographic Review, Vol. XV, N° 2, Nov. 1938, p. 38.

with Echoscope, for very shallow water :

From 3 ft. 9 to 11 or 32 3/4 fms., accuracy within 10 centimetres, gives 66 soundings per minute).

Hydrographic Review, Vol. X, N° 2, Nov. 1922, page 170.
— Vol. XI, N° 2, Nov. 1934, page 59.
— Vol. XV, N° 2, Nov. 1938, pp. 44 & 51.

(These descriptions correspond also to the Marconi apparatus, type 424). See also :

Hydrographic Review, Vol. XV, N° 2, Nov. 1938, page 42.

with bottom indicator, rotating optical system SCAM-Touly :

Former model: 5 ½ to 192 fathoms with 2 soundings per second and 5 ½ to 383 fathoms with 1 sounding per second.

Recent models: coastal type (82 fathoms) and navigation type from 2 ½ to 218 fathoms, and from 218 to 438 fathoms, and so on up to the limit of reception of the echo.

Hydrographic Review, Vol. XI, N° 2, Nov. 1934, page 46.
— Vol. XIII, N° 2, Nov. 1936, page 107.
— Vol. XV, N° 2, Nov. 1938, page 33.

with Marti Recorder :

Sounds from 2,2 fathoms up to the limit of range of ultra sounds by phases of 109 fathoms (200 metres) 1 sounding every 3 seconds.

Limit of range 273 fathoms with the projector S.4 ter, 547 fathoms with the projector S.7 bis.

Other model for hydrography from 2,2 to 55 fathoms and from 2,2 to 109 fathoms.

Hydrographic Review, Vol. XI, N° 2, Nov. 1934, page 51.

with electrolytic recorder SCAM-Touly (Marti license) :

Gives 1 sounding every 3 seconds. Sounds to 164 fathoms then lower by 3 successive phases of 164 fathoms.

Hydrographic Review, Vol. XIII, N° 2, Nov. 1936, page 110.
— Vol. XIV, N° 1, May 1937, page 111.
— Vol. XV, N° 2, Nov. 1938, page 35.

(These descriptions correspond also to those of the Marconi sounders types 429 et 439). See also :

Hydrographic Review, Vol. XV, N° 2, Nov. 1938, page 41.

British Admiralty Echo Sounding Machine (shallow water type, Mark II) with or without repeating transmitter, manufactured by Messrs. Hughes and Son (1925).

Scale 0 to 780 feet or 130 fathoms - 3 soundings per second.
Hydrographic Review, Vol. V, N° 1, May 1928, p. 132.

d° Mark III, equipped with a powerful transmitter :

From 0 to 250 fathoms; 1 sounding every 2/3 of a second.

d° Mark IV, with powerful pneumatic hammer :

From 0 to 500 fathoms, 1 sounding per second.
Hydrographic Review, Vol. VII, N° 1, May 1930, p. 99.

d° Mark VI, with recorder and headphones :

1 sounding every 5/8ths of a second, and sounds from 0 to 250 fathoms in 4 phases of 50 fathoms each.

Hydrographic Review, Vol. IX, N° 2, Nov. 1932, p. 141.

Deep Water Echo Sounder of the British Admiralty (Mark V - Oceanic Pattern) and for hydrographic surveys, manufactured by Messrs. Hughes and Son.

From 30 to 4.500 fathoms; 1 sounding every 11 sec. 1/4 with headphones.

Hydrographic Review, Vol. V, N° 1, May 1928, p. 138.

d° Model Challenger *and* Ormonde, *new Mark VI and Mark VII :*

Type recorder with phasing system down to 6,000 fathoms by phases of 250 or 500 fathoms, accuracy ± 1 fathom, ± 0.25 %. transmission cadence 2 ½ seconds, 5 seconds, 7 ½ seconds or 15 seconds.

Hydrographic Review, Vol. IX, N° 2, Nov. 1932, p. 137.
— Vol. X, N° 2, Nov. 1933, p. 130.

d° Standard Pattern, Mark X (Discovery II *type*) *with recorder :*

From 20 to 600 fathoms, by sections of 250 fathoms, with transmission interval of 2 ½, 5 and 7 ½ seconds.

Hydrgoraphic Review, Vol. XI, N° 2, Nov. 1934, p. 31.

Fathometer of the Submarine Signal Corporation of Boston (U.S.A.) (model 1925) with luminous white or red light indicator, Type 431.

Red Light 10 to 100 fathoms - 4 soundings per second. White Light 100 to 600 fathoms - 1 sounding every 1 ½ second. Thence down to 3.000 fathoms with headphones.

Hydrographic Review, Vol. V, N° 1, May 1928, page 143.

d° Universal Type, Type 432.

24 soundings per minute, small scale: oscillator type 399, big scale: oscillator type 324; red light from 2 to 125 fathoms, accuracy ½ fathom; thence white light and headphones down to 2,000 fathoms.

Hydrographic Review, Vol. VIII, N° 2, Nov. 1931, page 176.

Atlaslot of the Bremen Atlas-Werke (identical with the Fathometer of the Submarine Signal Corporation).

With luminous red or white light indicator.

Type 16: from 5 ½ to 274 fathoms (red light) and from 5 ½ to 820 fathoms (white light): 1 sounding every 1,5 second.

Type 20: from 2 ½ to 137 fathoms, and *Type 22* down to 274 fathoms, 1 sounding every 2 ½ seconds.

Universal type (Meteor) from 5 ½ fathoms down to the greatest depths, with indicator down to 101 fathoms, and thence headphones (4.500 fathoms).

Hydrographic Review, Vol. V, N° 1, May 1928, page 153.
— Vol. XI, N° 2, Nov. 1934, page 25.
— Vol. XV, N° 2, Nov. 1938, page 62.

Atlas-Echolot (high frequency) with Echograph Recorder :

With 2 scales: 3 ft. to 55 fathoms (7,5 soundings per second) and from 5 ½ fathoms to 547 fathoms. Echograph from 0 to 137 fathoms, or from 0 to 274 fathoms or from 0 to 137 fathoms and from 137 fathoms to 274 fathoms.

Hydrographic Review, Vol. XI, N° 2, Nov. 1934, page 29.
— Vol. XV, N° 2, Nov. 1938, page 65.

Acoustic sounding apparatus by successive shocks or detonations (Marti system, 1927) :

With hull hammer, rifle shots or detonating cartridges with recorder.

Hull hammer sounds 2 fathoms to 438 fathoms, accuracy to within ½ metre.

Rifle shots from 27 fathoms to 274 fathoms, accuracy to within 2 metres, record by phases of 274 fathoms, 1 revolution in 7,5 seconds, for great depths transmission cadence of 37,5 seconds or 2 ½ minutes.

Detonating cartridges: from 55 fathoms to 5.500 fathoms, accuracy to within 5 ½ fathoms.

Hydrographic Review, Vol. V, N° 2, Nov. 1928, p. 121.
— Vol. XI, N° 2, Nov. 1934, p. 38.
— Vol. XII, N° 2, Nov. 1935, p. 53.

Graphic Acoustic Sounder of the United States Navy (1924):

Hydrographic Review, Vol. VII, N° 2, Nov. 1930, page 108.

British Admiralty Echo Sounding Gear, Type 752 (1930) fitted with automatic recorder taking 3 soundings per second:

Sounds from 10 to 133 soundings, error ± 1 % with manipulator; thence with headphones.

Hydrographic Review, Vol. VIII, N° 2, Nov. 1931, p. 168.

Echograph of the Kiel Electroakustik Company:

Hydrographic Review, Vol. X, N° 1, May 1933, page 178.

Supersonic Shallow Water Echo Sounding Gear of the British Admiralty:

Magnetostriction system with straight scale recorder (Types MS I - MS IV) sounds from 1 ½ ft., accuracy 0.5 foot, synchronisation ± 1 %, accuracy of soundings ± 1 %.

Type MS I sounds from 0 to 35 fathoms - scale 7 fathoms for 1 inch of record.

Type MS II sounds from 0 to 35 fathoms, with, moreover, 3 phases of 25 fathoms up to 100 fathoms, same recording scale.

Type MS III sounds from 0 to 90 fathoms - scale 18 fathoms for 1 inch, up to 250 fathoms, with 4 phases of 50 fathoms.

Type MS IV sounds from 0 to 90 fathoms, with powerful transmitter.

96 transmissions per minute are effected with these types.

Types MS V to MS VIII are fitted with an indicator without recorder, with a range of 100, 125, 250 or 400 fathoms.

Hydrographic Review, Vol. XIII, N° 2, Nov. 1936, p. 87.
— Vol. X, N° 2, Nov. 1933, p. 160.
— Vol. XI, N° 2, Nov. 1934, p. 36.
— Vol. XIII, N° 2, Nov. 1936, p. 78.

d° *Types MS X - MS XII, recorder with rotating arm and curved scale:*

In *Type MS X,* specially suited to hydrography, the rotating arm has a big radius of 9 inches.

In Type MS XII, the radius of the rotating arm is 4 inches.

These two types have a double scale obtained by a speed reductor 1/6 or 1/5 or 1/2, with which the following scale combinations can be effected: 40 feet/40 fathoms - 60 feet/60 fathoms - 12/24 metres, in model MS X; or 60 feet/120 feet - 90 feet/90 fathoms - 120 feet/120 fathoms - 25/125 metres - 90/450 metres - 125/600 metres in model MS XII. Furthermore, by phasing, these ranges are increased respectively by 75 % in the type MS X and by 66 % in type MS XII.

Hydrographic Review, Vol. XIII, N° 2, Nov. 1936, page 85.

d° *Types MS XII - MS XV (Universal Echo Sounder).*

Hydrographic Review, Vol. XIV, N° 2, Nov. 1937, page 211.
— Vol. XV, N° 2, Nov. 1938, page 26.

Modulated frequency Sonic Ultra-Sounder Sadahiro Matsuo:

Hydrographic Review, Vol. XV, N° 1, May 1938, page 33.

Dorsey Fathometer (1933):

For shallow water: 1 to 20 fathoms, 20 soundings per second - accuracy 1 inch = 25 m/m.

Hydrographic Review, Vol. XIII, N° 2, Nov. 1935, page 50.

Marconi Echo Sounders :

Under the generic name *Echometer,* the Marconi Company presents apparatuses in every way similar to those of the Société de Condensation et d'Applications Mécaniques, described above, such as :

Marconi Echometers types 421 & 430, Langevin-Chilowsky :
Echometers N° 421 suitable for 160 and 360 fathoms, give 60 soundings in 70 seconds; those for 360 and 720 fathoms, give 30 soundings in 70 seconds.

Marconi Echometer, type 424, Langevin-Florisson, with echoscope: suitable for 45, 90 or 110 fathoms, it gives 45 soundings in 60 seconds.

Marconi Echometers, types 429 & 430, Langevin-Touly, with electrolytic recorder:

Recorder N° 429 suitable for 0 to 75 fathoms and 0 to 150 fathoms, gives 30 soundings per minute;

Recorder N° 430 suitable for 0 to 75 fathoms and 70 to 145 fathoms, gives 90 soundings per minute.

Also a portable Echo Sounder Marconi (quartz-steel):

For shallow water of 0 m. 30 to 36 metres (and of 0 to 18 metres with phasing) giving 187 soundings per minute.

Hydrographic Review, Vol. XV, N° 2, Nov. 1938, page 43.

and Marconi Supersonic magnetostriction Echo Sounders :

Navigation type 0 to 150 fathoms, 30 soundings per minute, and type for great depths 0 to 300 fathoms with 7,6 soundings per minute, with visible indicator and electrolytic recorder.

Hydrographic Review, Vol. XV, N° 2, Nov. 1938, pp. 57 and 59.

IX. Echo-Sounding Apparatus with Detonators.

a) Behm Echo-Sounder.

(See also: *Hydrographic Review*, Vol. II, No 2, May 1925, page 155).

A cartridge is placed in the cartridge chamber K from which it is expelled through the coiled pipe by means of compressed air P; it then reaches the firing apparatus U;

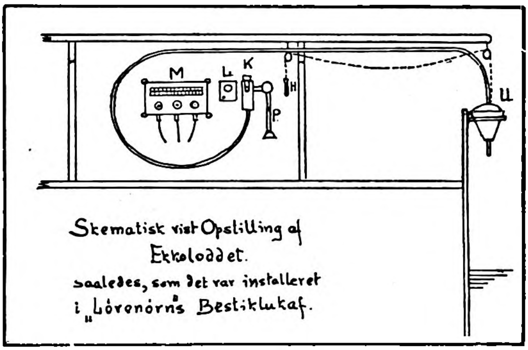


FIG. 8. — *Behm Echolot.*

when pressing a push bell, the cartridge is expelled from U, penetrates in the water and after a track of 75 centimetres below the surface of the water, a slow action fuse explodes 2 grammes of trinitrotoluol placed at the base of the cartridge. The noise of the explosion acts on a first microphone placed on the side where the explosion takes place. The echo is received by a second microphone on the other side of the ship, of which the hull forms a screen against the noise of the explosion.

The echo time is measured by an ingenious device called chronomicrometer, based on the motion of a disc suddenly brought into rotation by means of a spring at the instant of transmission and stopped by a tagential brake when the echo is received

The construction will be seen from the plan (fig. 9). A disc (1) which is balanced with the most complete accuracy and which revolves in ruby-bearings, is provided on its circumference with the armature (2), the nose (N) and teeth (Z). The armature can be affected by the electro-magnet (4 a). When the armature has been attracted, the spring (6) will be bent and the nose (N) will close contact with the stop (5), thus closing the circuit through the microphone (I). When the microphone is affected by the explosion, the current in this circuit will be cut off, the spring (6) will give the disc an impulse, and it will turn until it is stopped by the brake. This takes place at the moment when microphone (II) is affected, as the circuit of the brake is then cut off, and the brakeblock is pressed against the teeth of the disc by its spring. On the spindle is placed a small mirror by means of which the light from the lamp 11 is thrown onto the scale, where it appears as a narrow strip of light. The turning of the disc may thus be read off the

scale. Round the spindle (3) is a weak spiral-spring (the balance spring), the object of which is to swing the disc back, so that the armature of the disc is again brought near enough to the electro-magnet to be attracted.

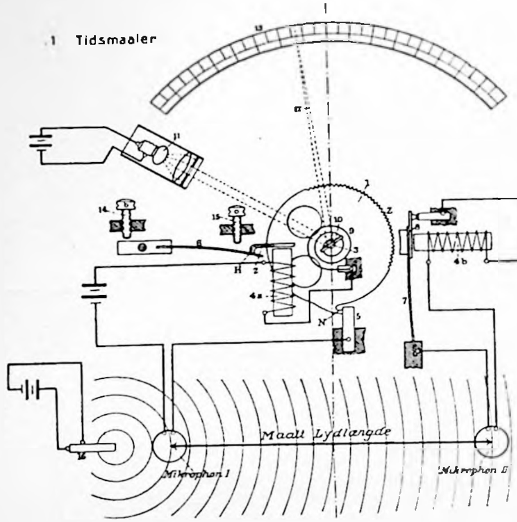


FIG. 9. — *Behm Chronomicrometer.*

The measuring apparatus is provided with 3 buttons (fig. 10). The button to the left, N° 1, is the main switch and by pressing it the batteries are connected and the lamp

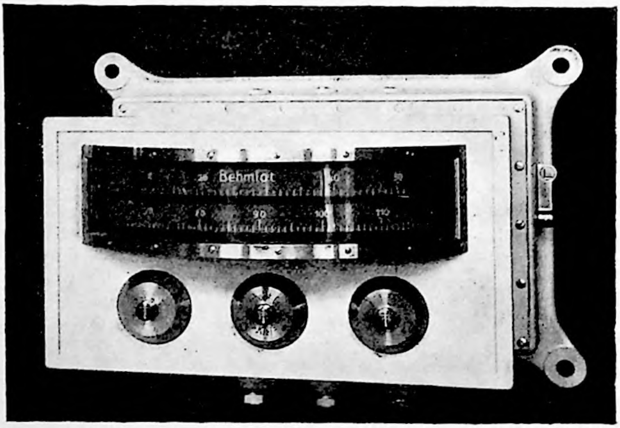


FIG. 10. — *Behm Echo Sounder, type 1.*

lit. By pressing the button in the middle, N° 2, the self-switches in the circuits of both microphones are short-circuited, which draws the brake back and the disc occupies its strained

position. By pressing the button N° 3 the circuit is closed through the firing-gear, by which the cartridge is ignited, and its bottom part is fired into the water.

This apparatus is also made with hand and dial (fig. 11).

Fig. 11. — *Hand and dial Behm Echo Sounder.*

b) **Echo-Sounder Marti.**

(See also: *Hydrographic Review*, Vol. V, N° 2, p. 121).

The charge which varies from a few grammes to a few hundred grammes in accordance with the depth to be reached, is primed by means of a detonator with a slow-action fuse. It is thereby possible to obtain the explosion at a sufficient depth below the wash of the propeller to avoid the air bubbles.

When sounding under way a "fish-lead" is used; the insulating core of the cable suspending the lead forms the firing circuit. (Fig. 12).

The noise of the explosion is received through the hull by a microphone which is placed in a thick cast iron case full of water.

Fig. 13 shows the mounting of the microphone on the hull; fig. 14 a section of the microphonic case; fig. 15 the microphone itself and fig. 16 is a sketch of the suspension of the microphone.

The echo coming from the bottom of the sea is received by the same microphone.

FIG. 12-16. — *Echo Sounder Marti*

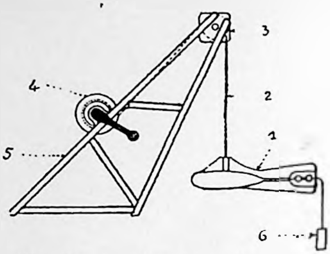


FIG. 12. — FISH-LEAD GALLOWS.

1. Fish-lead.
2. Suspending wire.
3. Sheave.
4. Hand-winch.
5. Gallows.
6. Detonating cartridge.

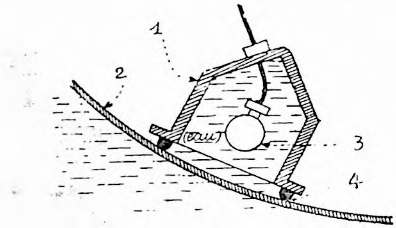


FIG. 13. — MOUNTING OF MICROPHONE ON THE HULL.

1. Metallic casing.
2. Bottom plating.
3. Microphone.
4. Rubber ring.

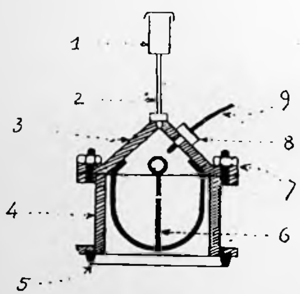


FIG. 14
SECTION OF MICROPHONE CASE.

1. Small reservoir.
2. Copper tube.
3. Conical cover.
4. Sleeve.
5. Rubber ring.
6. Small arches.
7. Cover tighteners.
8. Stuffing-box.
9. Electric cable.

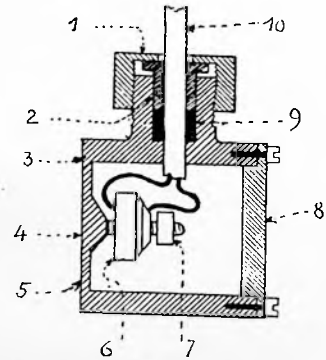


FIG. 15. — MICROPHONE.

1. Cap.
2. Stuffing-box.
3. Thick casing-side.
4. Reinforcement.
5. Thin casing-side.
6. Microphonic capsule.
7. Inertia-weight.
8. Cover.
9. Rubber packing.
10. Two-core cable.

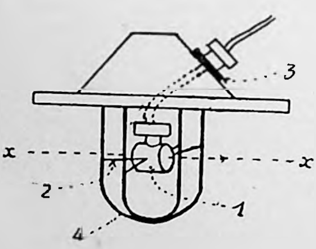


FIG. 16. — SUSPENSION OF MICROPHONE.

1. Microphone.
2. Steadying strings from microphone to arches.
3. Greased leather washers.
4. Small arches.

x-x. Parallel to fore and aft line of vessel.

The corresponding variations of the magneto oscillograph (Abraham type) are inscribed by two indentations on the band of an inked recorder; its stylus is a very fine nickel tube, one end of which rests on the paper and the other is connected by a rubber pipe to an inkwell. (See figure 17: Recording Apparatus).

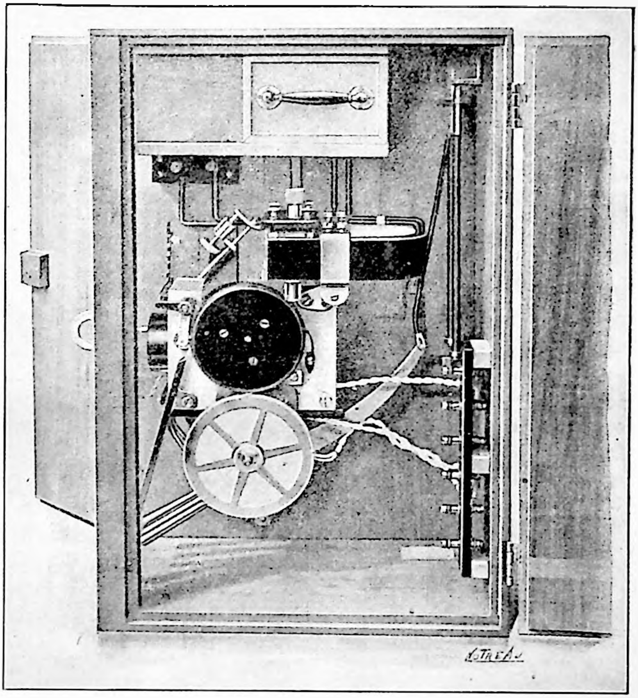


FIG. 17. — *Echo Sounder Marti. The recording apparatus.*

The rotation at constant speed is obtained by means of a clockwork mechanism, the spring of which is wound up by hand; the regularity of the speed, which is absolutely necessary, is assured by a regulating contrivance based on centrifugal force, the action of which is entirely mechanical; this regularity may, moreover, be controlled at any instant by the device of a coloured mark.

The recording apparatus of echo-sounder (Marti system) is fully described in *Hydrographic Review*, Vol. III, N° 2, July 1926, pages 89 & seq. (See figure 18).

The speed can be easily regulated to within less than one percent of its defined value and, in consequence, accurate indications of soundings may be obtained.

The noise of a gun cartridge shot into the water, from the bows of the ship, to avoid air bubbles, can also be used for producing sound. The pressure thus obtained is recorded in the same way as a detonation; the echo can still be perceived at depths of over 1.000 m.

The rifle is fitted with an electrical firing mechanism which enables it to be controlled by the Marti continuous sounding recorder.

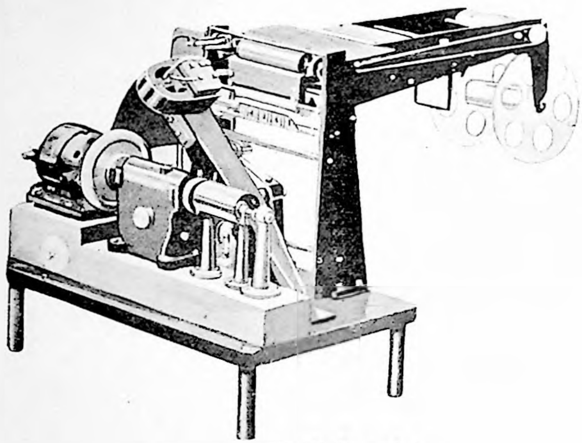


Fig. 18. — *Marti Recorder.*

The electric firing lock (fig. 19) comprises a metal casing A, inside which is an electro-magnet acting on a iron palm free to move around an axle B. To the continuation C of

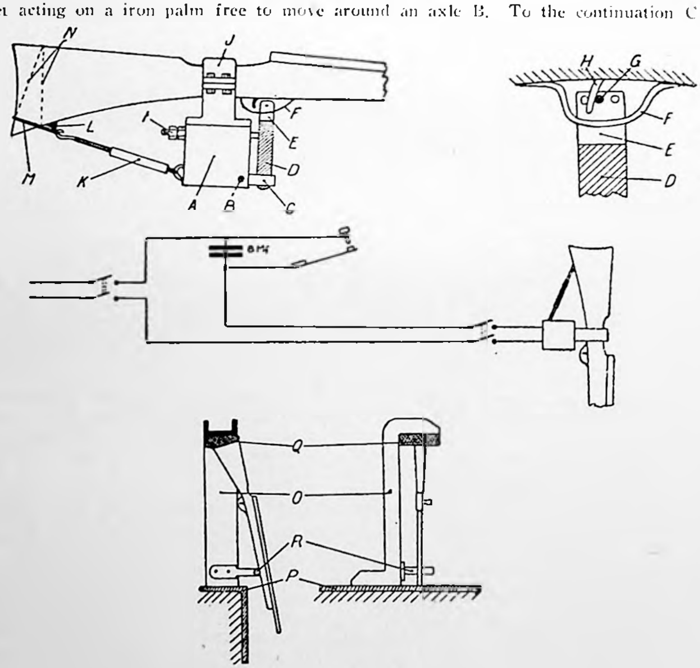


Fig. 19. — *Marti Echo Sounder for Deep water, using Rifle-Shots. Electrical firing mechanism.*

this palm, outside the casing, is rigidly fixed an arm D which branches at its end into two lugs E astride the trigger guard F. These lugs have holes at their ends, and a pin G is passed through them and the trigger guard F. This pin bears on the trigger H to fire the shot.

The end of the arm D is drawn towards the casing A by a strong spring hidden inside the latter.

The time interval between the breaking of the electric circuit and the bullet's entry into the water is about 0,04 second, corresponding to a distance of 30 metres (16 ½ fms.) on the depth graduation of the recorder. This interval is constant to within about 0.0015 second, which is equivalent to saying that it is possible to make the start of the acoustic phenomenon coincide with the passage of the stylus across the first line of the depth graduations, with a tolerance of about one metre on this scale.

A two-pole switch is fitted alongside the recorder to enable the operator to start and stop the apparatus at will. A similar switch is fitted near the rifle to enable the rifleman to stop the lock working altogether if he should think it necessary for any reason.

In the case of sounding by rifle-shots, the type of recorder used revolves at a speed of one revolution in 7 ½ seconds (8 r.p.m.); the total width of the graduations of the record strip corresponds to a depth of water of 500 metres (273 fms); and the machine can be used down to a depth of 5,000 metres (2,734 fms.)by successive steps of the emitter.

When penetrating in the liquid element, the shot from the rifle generally gives rise to three or four consecutive waves due to elastic phenomena in the water, all of which takes place in 6 or 8 hundredths of a second; if the same missile is turned round and expelled metal bottom foremost, only two waves occur. The round bullet of a revolver generally gives only two waves, the second (which corresponds to the hammer blow) being considerably more powerful than the first (which corresponds to the entrance of the projectile in the water); lastly the detonation of an explosive charge generally produces also two waves, which are separated by an interval varying with the charge utilised.

This secondary characteristic is a great drawback when utilising this method of sounding in shallow water, and consequently it is generally only used for depths greater than 100 metres. On the other hand, it has the advantage of specifying the sonic waves utilised, by imparting to its record a particular form found again in the echo, which enables the identification of the latter in spite of the numerous parasitic noises of same power.

In examining great depths it is not generally necessary to take soundings at very short intervals. Consequently it is usual to make use of an automatic reducing device for the frequency of emission, which is fitted to the recorder and which limits the shots at will to one shot every 37 ½ seconds or even one shot every 2 ½ minutes. In spite of this deliberately wide spacing of the shots, the recorder produces sounding diagrams of very great clearness, on which the depth profiles can be traced without the least ambiguity.

The installation of this type of machine on board is extremely expeditious, and entails very little cost, the acoustic devices being fixed without piercing the hull. For the same reason the sounding machine can be very easily transferred from one vessel to another.

X. Echo-Sounding Apparatus with Blow of a Hammer on a Metal Plate.

British Admiralty Echo-Sounder.

(See also: *Hydrographic Review*, Vol. V, N° 1, May 1928, p. 132; Vol. VIII, N° 1, May 1930, p. 99; Vol. IX, N° 2, Nov. 1932, p. 141; Vol. X, N° 2, Nov. 1933, p. 130; Vol. XI, N° 2, Nov. 1934, p. 31).

The transmitter type A/S2 (fig. 20) is constituted by a circular horizontal steel plate set in motion by a cone-shaped metal hammer with vertical axis placed in an electro-magnet with two coils. A cylindrical spring, placed in the top part, tends to move the hammer from top to bottom, but it is maintained over the plate by the action of the current.

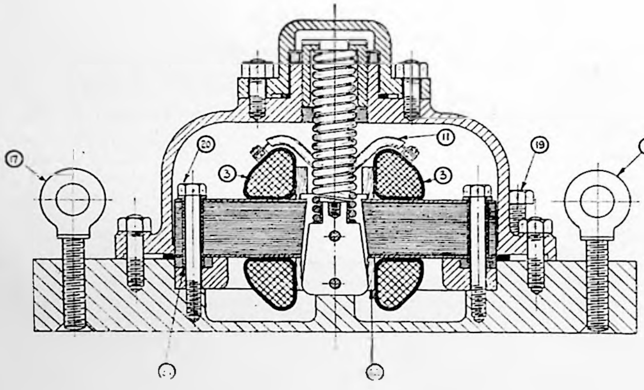


FIG. 20. — *Transmitter, type A/S 2.*

When the circuit of the electro-magnet is interrupted for a short space of time, the hammer propelled towards the bottom by the spring, gives a sharp knock on the plate; the current being connected immediately attracts the hammer which returns to its original position and presses on the spring. The plate vibrates with its own frequency : 1.250 or 2,000 according to the case. This apparatus is fixed in the interior of the ship on a small tank filled with water under pressure.

In the case of great depths, the electric hammer is replaced by a hammer worked by compressed air. Each time the current is broken, the piston is forced down against the diagram by compressed air. After striking the diaphragm the piston is forced up by air pressure underneath and again held by the magnet on reaching the top of the cylinder. (Fig. 21 and 22).

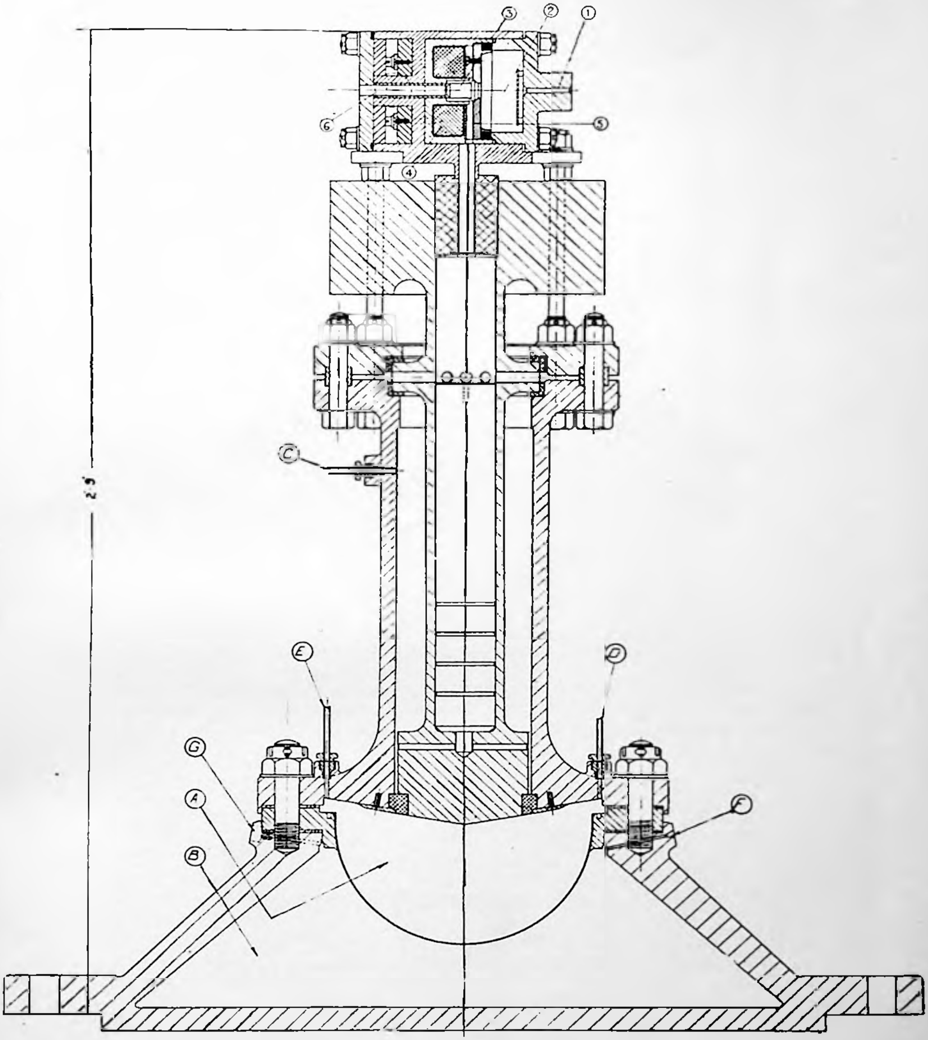


Fig. 22
British Admiralty deep-sea balanced transmitter.

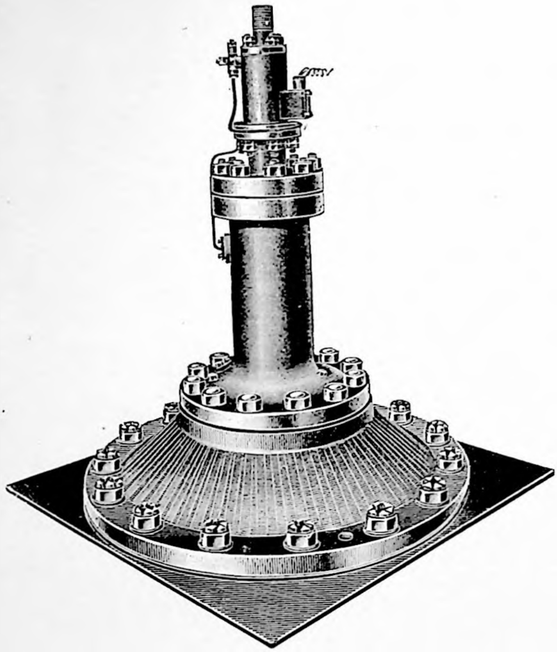


FIG. 21
British Admiralty deep-sea balanced transmitter.

The receiver (fig. 23) is formed by a microphone fixed in the reinforced central part of a diaphragm, the frequency of which is the same as that of the sound made by the hammer. The whole, protected by a lid, forms the top part of a small tank filled with water of which the hull constituted the bottom.

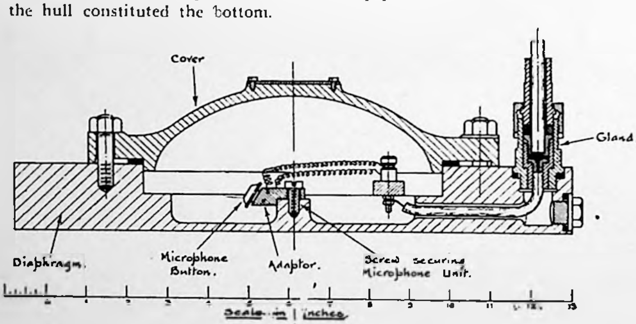


FIG. 23. — *Receiving Hydrophone.*

The adjustment of the transmitter and receiver increases the range and enables an easy separation of the echo from parasites. The receiver and transmitter are placed far one from the other in order that the microphone may not be affected by the noise of transmission.

In the case of great depths reaching 10 000 m., the microphone is mounted at the end of a watertight vertical tube and can be plunged into the water below the ship. (Fig. 24 & 25).

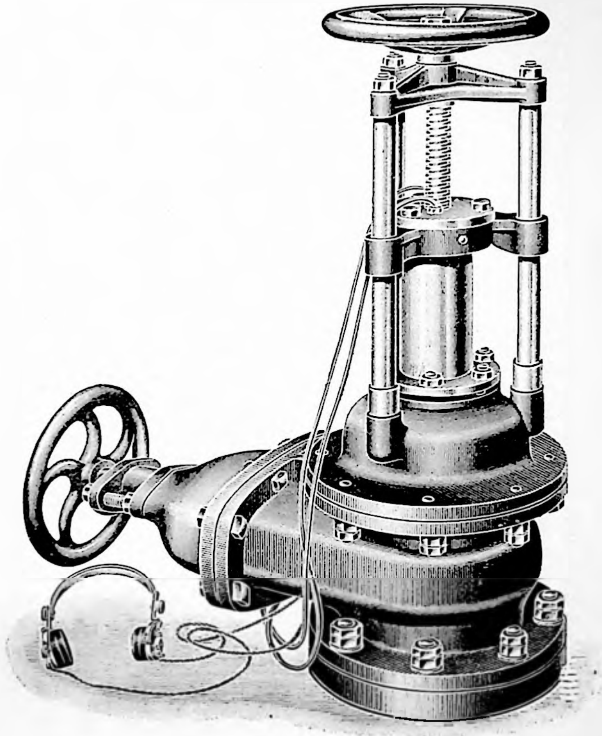


Fig. 24. — *British Admiralty deep-sea hydrophone, sluice valve type.*

The echo time measuring apparatus (figures 26 and 27) consists essentially of an electric motor M, the motion of which is governed by a centrifugal governor, moving at a constant speed vertical discs 2 and 3 (figure 26), carried by the same axis, each of which is fitted with a pair of brushes 6 and 7.

The brushes of the disc (2) when passing over the insulating segment (4) break the circuit of the magnet of the hammer during a very short time which produces the sound signal. The primary circuit of the induction coil comprises the receiving microphone. The brushes of the disc (3) close the secondary circuit of this coil on which a telephone is branched (11). But the telephone only rings when the direct or reflected sound-wave hits the receiver during the short time when the brushes pass over an insulated key (5).

A hand-lever bearing a large drum E, with depth graduations enables one to vary the position of the insulated key (5) on the disc (3). The operator turns the hand-lever until he hears the cho in the telephone; he then reads the depth on the drum. The angle to which the hand-lever has been turned from zero is equal to the angle to which the disc (3) has turned between the time of the start of the sonic signal and the return of the echo.

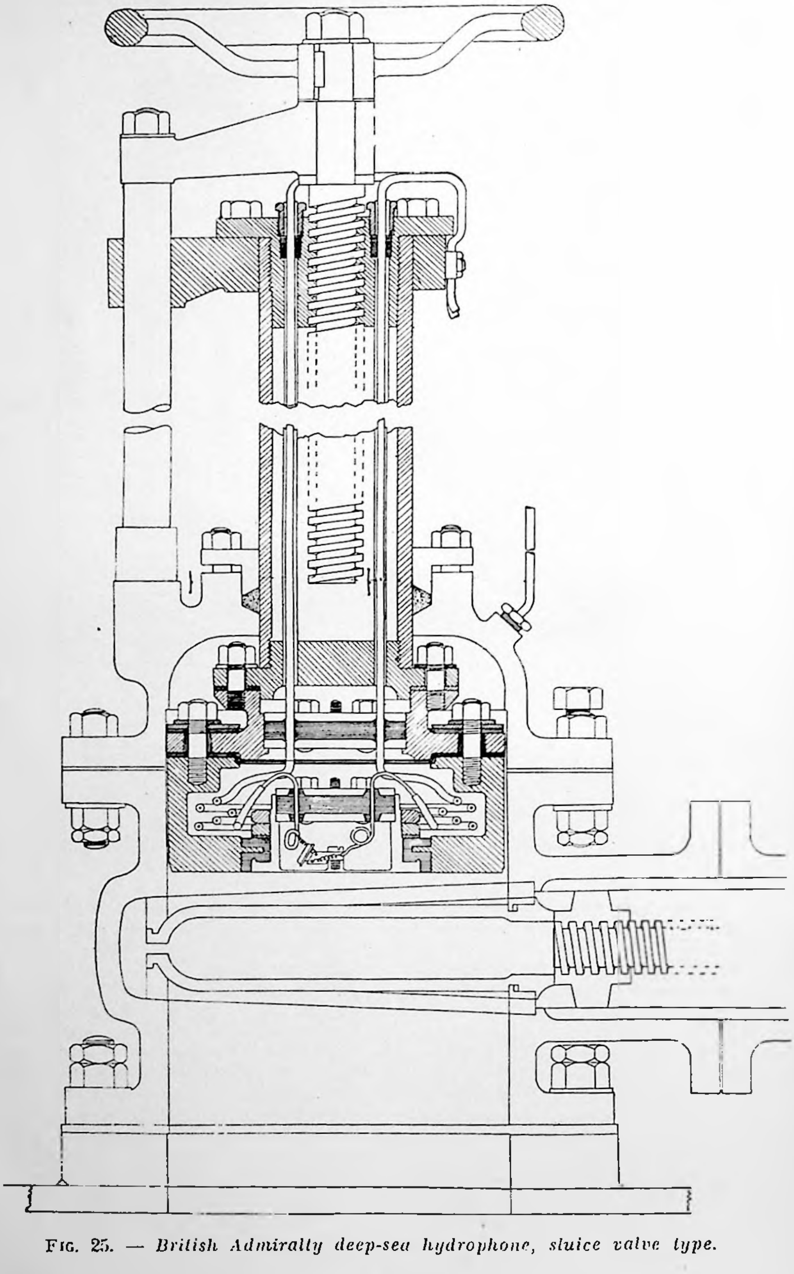


FIG. 25. — *British Admiralty deep-sea hydrophone, sluice valve type.*

This apparatus has the great advantage of being selective in the following manner : it reduces to a very short interval of time the necessary period of awaiting the echo, it avoids most disturbances and inconveniences due to noise on board the ship.

In great depths the number of revolutions must be taken carefully into account, for 360° in 1/2 a second corresponds to a depth of 375 metres (205 fathoms), and it is most advisable to distinguish carefully between a depth of h metres and a depth of h + n 375 metres, n being a whole number.

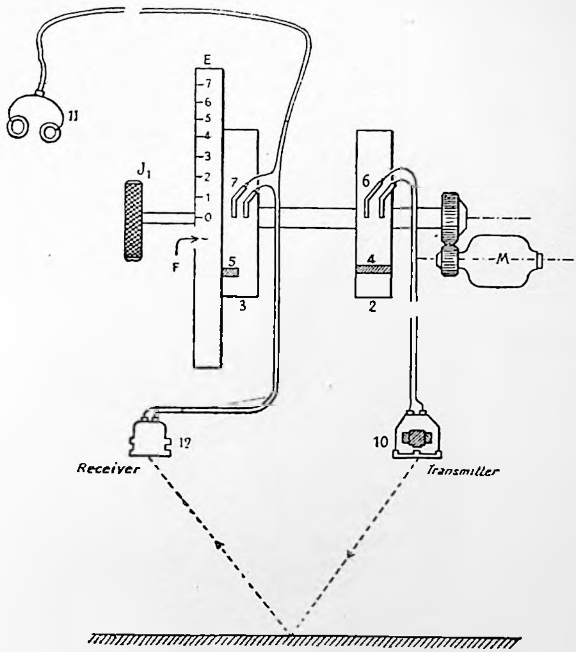


FIG. 26. — *British Admiralty Echo time measuring apparatus.*

The accompanying photograph (fig. 27) gives a general view of the receiving gear which may be attached to a support, or chart-house wall.

In order to take into account, in shallow water, the distance which separates the transmitter and the receiver and the errors of parallax therefrom, it is possible, in certain cases of installation, to introduce near the needle a correcting device in order to obtain directly an exact reading of the depth.

Accuracy, in shallow waters, may be relied upon within 1 foot, and soundings may be obtained in two feet of water or even less.

It has been found convenient to add to the sounder an electrolytic recorder, the telephone apparatus being used only as an auxiliary.

The recording takes place on a band of paper rendered sensitive with starch iodine, and the inscribing stylus mounted on ball bearings running between fixed guides, is moved along its track by a special adaptation of a dog-clutch type of mechanism driven by a chain; the chain carrying the dog completes its cycle in the echo-time of 1.000 fathoms, and the time of traverse of the stylus across the paper is the echo-time of 250 fathoms.

At the end of the paper, the stylus is lifted off the paper, returned to its starting point

by a return spring, and again lowered on to the paper in readiness for the dog-clutch to take up the drive on its return, the dog going round with the chain.

A scale from 0 to 250 fathoms is fixed over the paper so that the position of the stain record made by the stylus can be read off immediately. Other scales are provided, com-

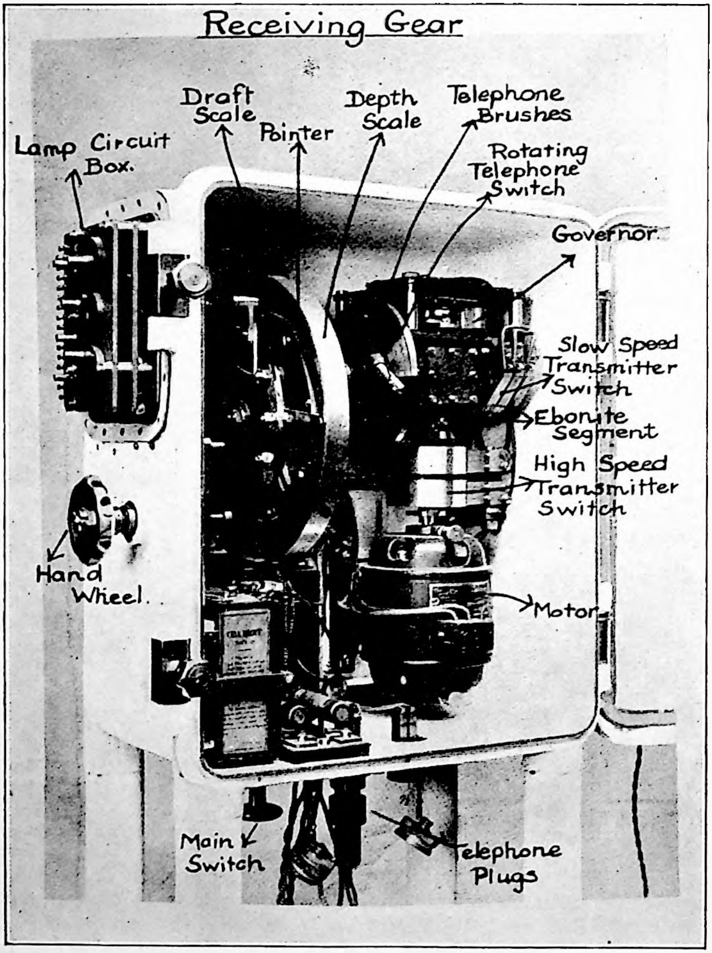


FIG. 27. — *Receiving gear.*

Hand-wheel.	Governor.
Lamp circuit box.	Slow speed transmitter switch.
Draft scale.	Ebonite segment.
Pointer.	High speed transmitter switch.
Depth scale.	Motor.
Telephone brushes.	Main switch.
Rotating telephone switch.	Telephone plugs.

pensated for the shrinkage of the paper in drying, for reading off the depth shown on the dried paper when the results are worked up.

A control for the sensitivity of the hydrophone is included in the gear which enables stray disturbances arising during the passage of the stylus across the paper to be eliminated.

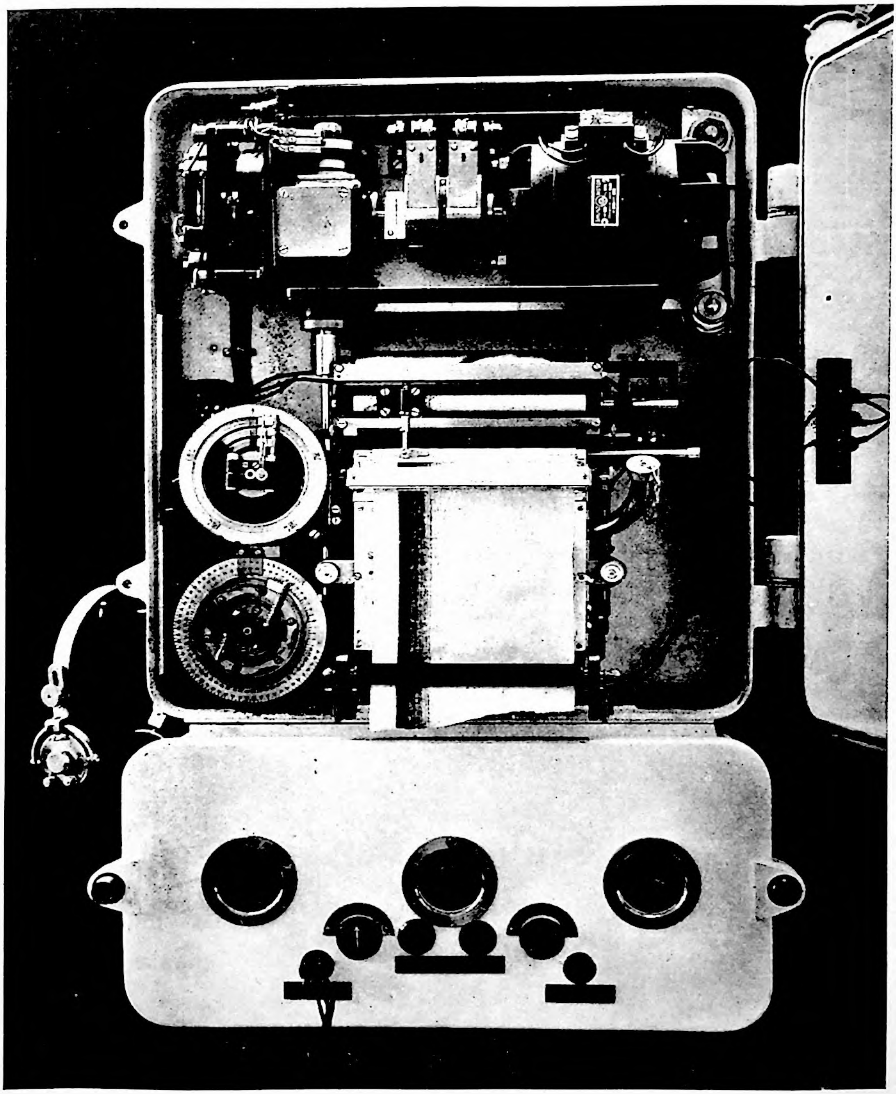


Fig. 28. — *British Admiralty Echo Gear, Mark VI*

The incoming signal picked up by the hydrophone is passed through a transformer coupling to a valve amplifier and thence to the recording stylus. Any disturbance reaching the hydrophone during the passage of the stylus across the paper is recorded on the paper in the following manner : the paper is sensitised with iodide-starch and is kept moistened, which renders it sensitive to the passage of a weak electric current, and this weak current from the stylus passes on to the paper on which it produces the appearance of a sharply defined sepia stain. This sepia stain is due to the liberation of iodine.

The brushes of the hammer revolve also in an echo-time of 1,000 fathoms (1,829 m.), i.e. 2 ½ seconds.

The hammer control circuit is broken each time the rotating brushes pass the gaps in the two segments of the stationary disc. This disc can be rotated by hand from the outside of the case and the various step by step advances in the emission of the signal have been obtained. The dial is engraved from 0 to 1,000 fathoms and the 200 fathom steps are obtained very accurately by a special clicker catch arrangement.

Driven from the back of the rotating brush shaft is a Maltese Cross motion which operates a rotary selector switch controlled from a small selector switch which can be mounted at any convenient place near the instrument; this enables the operator to regulate the interval between successive signals, the intervals available being 2 ½, 5, 7 ½ and 15 seconds respectively, corresponding to 1,000, 2,000, 3,000 and 6,000 fathoms.

The signal emission arrangements thus permit of a signal every 2 ½...15 seconds with either 0, 200, 400, 600 or 800 fathoms advance with regard to the moment when the recording stylus passes zero.

An additional apparatus enables the zero and the hour to be also recorded.

The same band of paper can be used for 60 hours' sounding. An electrolytic pen is also provided with which notes can be made on the record itself (fig. 28).

b and c) **Echolot of the Atlas Werke of Bremen and Fathometer** (Shallow Water) **of the Boston Submarine Signal Corporation.**

These two sounders of very similar construction, and a short description of which is given in the following chapter, can also be used with impact oscillators (type 399, for shallow water (fig. 29).

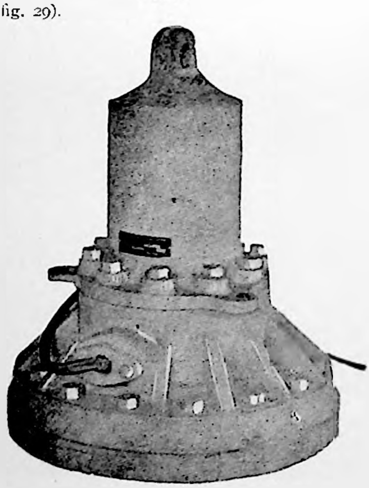


FIG. 29. — *Impact Oscillator, type* 399.

This oscillator is provided with a plunger which is lifted against the action of a spring by a strong direct current electro magnet. When the current through the magnet ceases, the spring drives the plunger with uniform strength at each blow against the diaphragm. The oscillator may be suspended in a large water tank, in which case the sound is transmitted from the diaphragm through the water surrounding it to the ship's skin and thence to the ocean, or it may be mounted, depending on the construction of the ship, with the diaphragm directly in contact with the ship's skin, in which case no water tank is required.

This oscillator is operated by direct current from the ship's line.

d) **Hull Hammer Sounder (Marti System).**

The Marti sounder described above, paragraph IX (b), can also be operated by blows from a hull hammer. (Fig. 30).

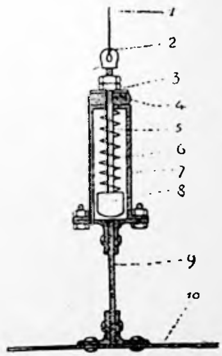


FIG. 30. — *Spring Hull-Hammer.*

1. Cable.
2. Eye for cable.
3. Nuts and metal washer.
4. Rubber washer.
5. Hammer-rod.
6. Spring.
7. Cylinder.
8. Hammer.
9. Frame.
10. Bottom plating.

The hull hammer is mounted on the framing of the vessel below the water-line, at some distance from the microphone, so that the indentation caused by the departing wave may be of the same order as the indentation caused by average echoes.

A steel cable connects the hammer to the control handle mounted near the recording apparatus, so that one man can take the soundings. (Fig. 31).

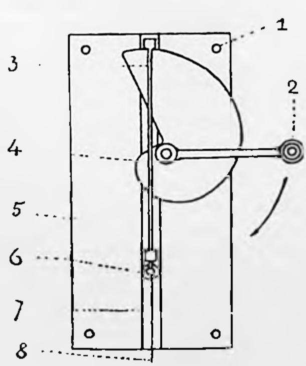


FIG. 31. — *Hammer controlling handle.*

1. Assembling bolts.
2. Handle.
3. Stirrup.
4. Cam.
5. Plate.
6. Eye for cable.
7. Guide.
8. Cable.

The handle apparatus consists of two rectangular plates secured by bolts, a groove running down the length of each of them, to provide a guide in which moves a rod (fig. 31). A spiral shaped cam, actuated by a handle, is mounted on an axle and moves the rod up and down: the rod is fitted with an eyebolt to which the control cable is secured. When the handle is turned the cam moves the rod which compresses the spring by the intermediary of the cable: the sudden fall and hammer blow are produced at the instant when the point of the cam disengages the rod bolt: the manœuvre does not require any special precaution: it may be repeated frequently at short intervals.

To prevent a second blow in rebounding, a thick indiarubber washer, on which rests a metallic washer attached to the rod, is inserted on the upper part of the cylinder of the hull hammer; the adjustment is made by means of a nut and lock-nut, so that in the position of rest the head of the hammer is withdrawn about two millimetres from the frame on which it should beat.

A striking apparatus can also be utilised with the Marti recorder (fig. 32). This apparatus comprises an anvil and an electrically driven hammer.

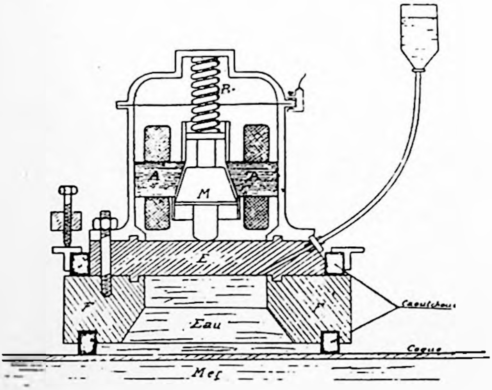


FIG. 32. — *Marti Hammer Transmitter.*

The anvil E, a big disc of special steel, rests on a cast-iron ring F, fitted with a rubber joint underneath and solidly attached to a plate in the bottom of the sounding craft. The cavity thus formed between the anvil and the hull is filled with water, giving ample continuity in the medium between the anvil and the bottom without making it necessary to pierce the hull. The hammer M is forced vigorously downwards by a strong cylindrical spring R, but can be raised by a powerful electromagnet A. Thus, when the current is broken, the hammer is violently projected on to the anvil the energy absorbed by the shock being 0.3 kilogrammetre (2.2 ft. lb.). To avoid ill effects due to self-induction, the electric current is considerably reduced before rupture by interposing a resistance, the hammer however being still held up. The rotating arm of the recording apparatus which controls the working of the striker is provided with two switches for this purpose, one of which establishes the normal current, the other the reduced current.

To prevent the emissions (except for the check emissions) being recorded, the oscillograph circuit passes through a circuit breaker attached to the anvil. The circuit-breaker is very simple, being composed of a weight actuated by a small cylindrical spring, which automatically breaks the circuit at each hammer stroke.

Only one microphone is utilised and a recorder with inked or smoked paper. The electric apparatus is regulated in such a way that the starting peak can be made to appear or not at will: generally it is allowed to appear once in twenty times and serves solely as control of the fixity of the zero.

XI. Echo-sounding apparatus using an audible frequency transmitter.

Echo-Sounders originally used in the United States Navy, adopted as sonic generator, the Fessenden oscillator which was previously employed for sub-marine signalling. In this transmitter (fig. 33), number 1 indicates a rigid diaphragm in contact with the water, number 2 represents one-half of a powerful electromagnet rigidly attached to the diaphragm,

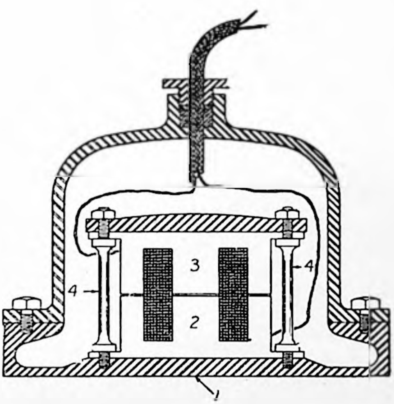


FIG. 33. — *Fessenden Transmitter.*

and number 3 represents the other half of the electromagnet which is suspended in position by the elastic steel rods represented by numbers 4. When an alternating current is passed through the magnetizing coil, the suspended half of the magnet vibrates back and forth alternately compressing and stretching the rods by which it is suspended and exerting a powerful thrust and pull on the heavy diaphragm that may equal several tons. Because of the incompressibility of water, it becomes necessary to exert great forces on the diaphragm to produce even a slight amplitude of motion.

Oscillators of this type were adjoined to the Sonic Depth Finder type S.E. 1378 of the United States Navy.

a and b) Fathometer of the Submarine Signal Corporation of Boston and Atlas Echolot of the Bremen Atlas Werke.

(See also: *Hydrographic Review*, Vol. V, N° 1, May 1928, p. 143 and 153; Vol. VIII, N° 2, Nov. 1931, p. 176; Vol. XI, N° 2, Nov. 1934, p. 25; Vol. XV, N° 2, Nov. 1938, p. 62).

These two apparatus are similar in every way.

The Universal Fathometer type 432, comprises two transmitters, oscillator type 399 for shallow water (exterior scale of the indicator, red light) with hammer, which has been mentioned above, paragraph Xc and oscillator type 324 (fig. 34) used for great depths (inner scale of the indicator, white light). In the latter type, a thick iron diaphragm is connected with an electromagnet receiving a current of a frequency of 525 cycles generated

by a special electric equipment. When an alternating current is passed through the windings of this electromagnet the diaphragm is made to vibrate to and fro and thus produce powerful sound waves in the water.

The frequency of the alternating current is such as to suit the pitch of the oscillator diaphragm. As long as the alternating current is maintained in the magnet, the diaphragm continues to vibrate emitting a powerful note having a frequency of about 1,050 cycles.

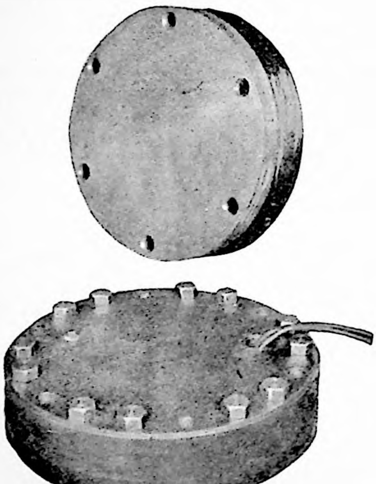


FIG. 34. — 324 *Oscillator.*

The submarine oscillator is a device which has been heard under water at a distance of 80 miles and which can emit enormous energy in a very small space of time.

The frequency of the alternating current is such that the magnetic pull pulsates with the natural frequency of the diaphragm, and a high pitched musical note results. As a consequence of the musical note, the echo is easily distinguished from water noises and accidental blows against the ship's hull.

The circuit of the oscillator is normally open, but is closed for a very small fraction of time by a cam in the Fathometer Indicator at the instant that the signal should be emitted.

The reflected sound waves act on the hydrophones.

Three hydrophone receiving units, two for the shoal and the third for the deep range, are included in the installation.

For the shoal range two hydrophones comprise the sound receiving unit. These hydrophones are mounted in a small tank of water bolted against the inner skin of the ship, the hull forming one side of the tank. They are essentially water-tight telephone transmitters and are particularly sensitive to the highly damped signals produced by the impact oscillator.

For the deep range a single hydrophone is provided. This hydrophone is mounted in a separate tank near the keel where it will be favourably located for receiving the less powerful signals echoed from great depths. Although similar in principle to the hydrophones used for obtaining soundings in the shoal range, the general appearance and characteristics are distinctly different and this hydrophone is especially tuned for efficient response to the sound waves produced by the Type 324 Oscillator.

Control of the sensitivity of the hydrophones is obtained by regulation of the knob located at the lower left side of the Indicator control panel.

A filter placed between the microphone and the amplifier allows passage only to frequencies in the neighbourhood of the sound wave emitted, this eliminates parasites which are generally of low frequency.

The Fathometer Indicator (fig. 35 & 36), contains the time-measuring apparatus and other switches. This measure is obtained by revolving an opaque disc at

Fig. 35. — *Fathometer Indicator.*

a uniform and known speed. This disc carries a pointer, in reality a narrow slot in the disc, which passes near a fixed scale on the front of the Indicator calibrated in fathoms. At the instant that the slot in the disc passes the zero of the scale, a circuit is closed by a cam, which energizes the oscillator for an instant and causes it to emit a very short

train of submarine sound waves of a frequency of 1 050 cycles per second. These sound waves are reflected from the bottom of the ocean and, when they reach the vessel, actuate the hydrophone, thereby causing a light back of the slot to be illuminated and thus indicate to the observer their arrival. The position of the slot relative to the fixed scale can then be read and that reading indicates the depth of water.

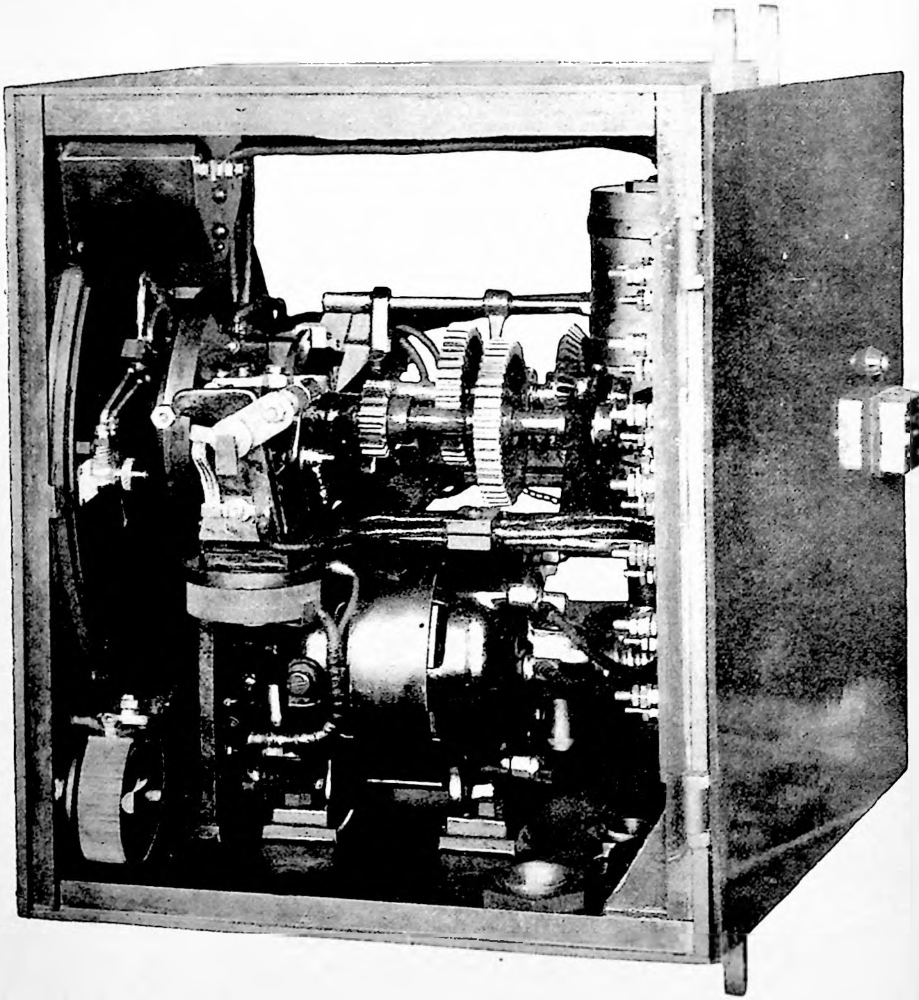


FIG. 36. — *Interior view.*

For measuring the depths of shallow water, the illuminant, used back of the slot, is a neon tube which is connected with the hydrophone in such a way that the tube is lighted when the hydrophone is agitated by the echo of the submarine signal created by the oscillator. The rapid succession of signals makes it extremely easy for the observer

to read the depth on the scale at a point where the light flashes. This light is reddish in colour so that the scale for shallow depths, i.e. from 10 to 100 fathoms, is frequently spoken of as the "Red Light Method".

The disc in the red light method makes about one revolution in one quarter of a second which corresponds with the time which it takes a submarine sound to travel to and from a reflecting surface 100 fathoms distant. If greater depths are to be measured, it is necessary to revolve the disc less rapidly. Provision is made in the Fathometer Indicator whereby the trains of gears employed can be quickly changed so that the disc, instead of revolving four times each second makes a single complete revolution in one and one-half seconds. This change in speed necessitates a new scale on which depths can be read directly up to six hundred fathoms. When the disc is revolving at this slower speed and measurements are to be made in deep water, a second slot on the disc is employed which is diametrically opposite that used for shallow water. Therefore, when the gears are shifted to cause the disc to revolve more slowly, a small incandescent lamp back of this second slot is lighted permanently and, shining through the slot, makes a finger of light which moves over the outer scale of the Fathometer once in every one and one-half seconds. This light is that of an incandescent light, hence this method of reading depths is frequently spoken of as the "White Light Method".

Interlocking with the gear trains are two cam systems, one of which operates the Type 399 oscillator for the shoal range once in every 8 revolutions of the red light, and the other of which operates the Type 324 oscillator for the deep range once in every two revolutions of the white light. The cams are arranged so that either one or the other of the oscillators operates, as indicated above, as the corresponding light passes the initial point on its scale. The distance, therefore, on the dials through which either light has moved when the echo signal returns, actually measures elapsed time, but inasmuch as the dials have been calibrated in fathoms, the correct depth is read directly from the position of the lights on their corresponding dials.

The speed of rotation of the motor in the Indicator is shown by a "reed" frequency meter located above the two dials. When the middle reed is vibrating, the motor is operating at the proper speed for making either shallow or deep soundings. The motor speed may be increased by turning the Speed Control at the lower right-hand side of the Indicator control panel clockwise, or decreased by turning it counter-clockwise.

In the white light method for great depths, the observer uses one or two telephone receivers so connected that they are responsive to the echo. The observer, when he hears the echo, notes the position of the illuminated slot pointer on the outer scale.

The change of the Fathometer from shoal range sounding (Red Light Method) to deep range sounding (White Light Method) and vice-versa, is obtained by a turn of the switch button in the middle of the control panel on the front of the Fathometer Indicator. This switch controls the circuits so that either the Red Light or the White Light Methods of soundings can be used as desired.

This Fathometer allows visual indications of depth in a range from about 2 to 125 fathoms to be obtained automatically with an accuracy to within one-half of a fathom. Depths above 125 fathoms are measured by audible means with an accuracy which is dependent upon the experience and skill of the operator. Depths as great as 1,500 or 2,000 fathoms may be measured with an error not to exceed 5 or 10 fathoms.

The German apparatus of Atlas Werke are in general founded on the same principle as the Fathometer. A recorder, called *echograph*, is used in Germany as well as the optical indicator; this echograph comprises an oscillograph of which the stylus marks a short stroke when the echo arrives in the white wax film with which the paper is covered, so that the red ground colour of the latter becomes visible and marks the depth. The single strokes follow so closely to one another that they result in an uninterrupted depth curve.

The actual width of the record paper is 120 m/m (4 ¾ in.) with the scale showing 0 to 250 m., i.e. 1 m/m for 2 m. of water. The scale can also be used to show 500 metres depth, or switched over to show 0 to 250 m.; or 250 to 500 m., in each case utilising the full width of the recording strip. The supply of paper enables the apparatus to work for about 125 hours. The wax-coated paper renders the use of ink unnecessary and has the advantage of unlimited durability. The paper strips are graduated in metres so that the depths can be read off directly.

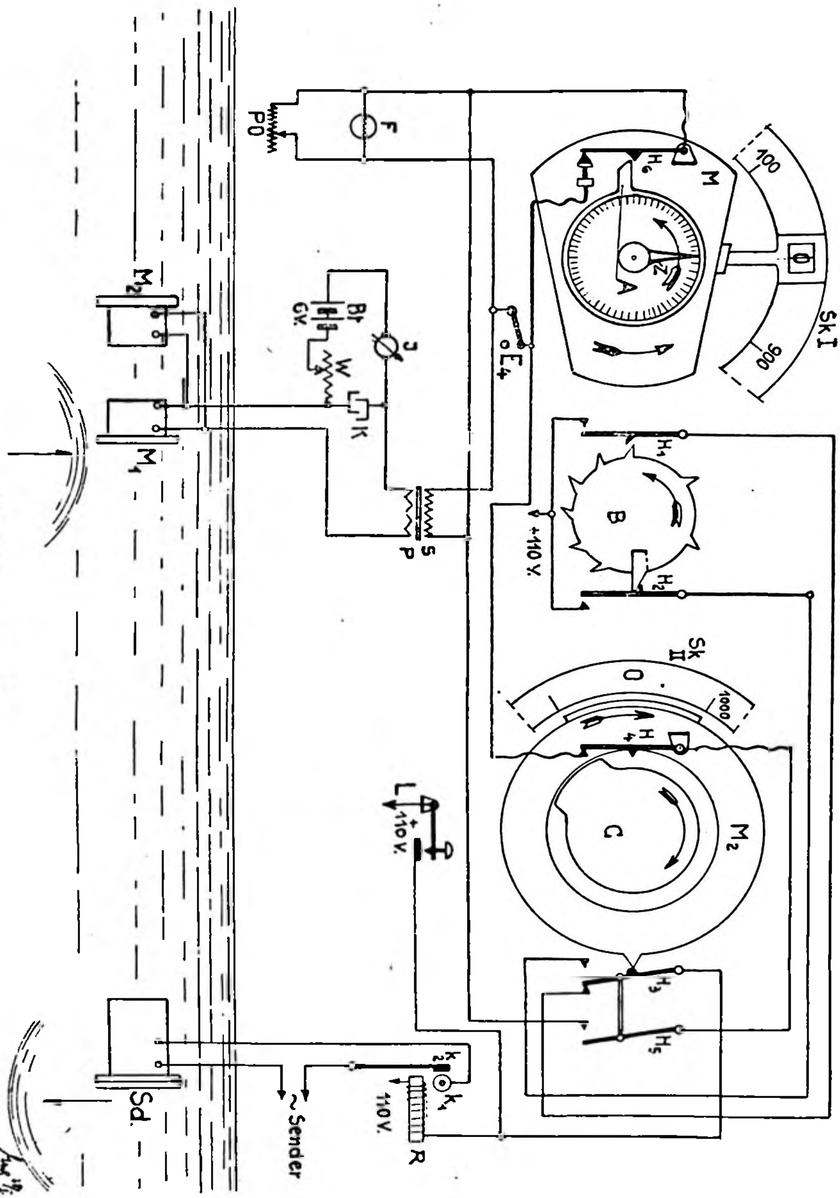


FIG. 37. — *Signal-Lot.*

c) Signal-Lot of the Signalgesellschaft, Kiel.

This Echo-Sounder which takes soundings from 50 metres (25 fms) down to the greatest depths, was utilised during the German Atlantic Expedition of *Meteor* (1925-1927). It comprises a powerful electromagnetic transmitter, type Hahnemann & Hecht manufactured by the latter. The time of the echo is measured by comparison with the duration of rotation of a disc actuated by a uniform rotary movement. A short description of this sounder is given in *Hydrographic Review*, Vol. V, N° I, May 1928, page 161 (see fig. 37).

d) Dorsey Fathometer of the Coast and Geodetic Survey.

(See also: *Hydrographic Review*, Vol. XIII, N° 2, Nov. 1935, page 50).

For sounding shallow water, the Technical Department of the Coast and Geodetic Survey has established an accurate sounder in which the correct speed of the indicator is assured at all times.

FIG. 38. — *Dorsey Fathometer.*

The indicator consists of the rotor and the stators and a starting motor to bring the rotor up to synchronism, the desire being that the indicator shall run either at its correct speed or not at all. The motor is run by current taken from the fork circuit and amplified by a pair of power triodes. A tuning fork can easily be kept on its frequency with an

error less than 0.1 per cent, and if one uses temperature control of the fork, any desired accuracy may be obtained. With a fork made of steel having a low temperature coefficient of modulus of elasticity, temperature control is unnecessary. In any method of controlling speed by a governor no correction to the speed can be made until the speed has changed, whereas with a tuning fork the regulation is almost continuous. With this fork frequency, the velocity of calibration is 820 fathoms per second, or 1,499.6 metres per second. On the same shaft with the rotor is a disc having a narrow slot and just back of this disc there is a neon tube bent in the form of a circle so that when the neon tube is illuminated it will be seen through the slot in the disc. In front of the disc is a glass scale calibrated to 20 fathoms, the fathoms being subdivided into feet. The diameter of the scale is about 8 inches so that the length of the scale is 25 inches, thus giving 0.2 of an inch for 1 foot of depth or 1.8 centimetres per metre depth if the scale is calibrated in the metric system. These divisions can easily be read to tenths so that it is possible to read to tenths of feet or to 10 centimeters on a metric scale. The dial is frosted slightly so that little light is reflected, making the flashes more readily perceptible. At one side near the teeth of the rotor there is placed a small neon tube, which is actuated from the 1 025 cycle alternating current, giving 2,050 flashes of light per second on the teeth making it appear to stand still when the rotor is in synchronism with the tuning fork.

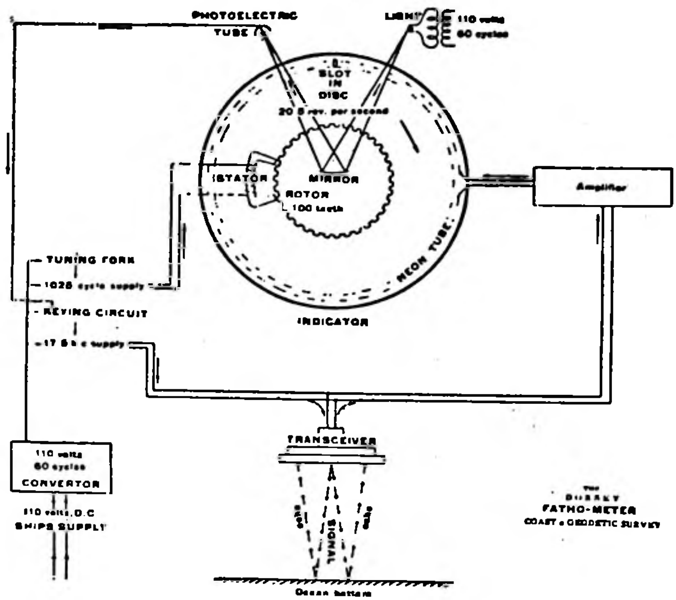


FIG. 39. — *Dorsey Fathometer.*

In order to send the signal, contacts were found unreliable, due to chattering, so a small concave mirror is rotated on the shaft to reflect light from an incandescent lamp to a photo-electric tube.

The signal is therefore sent without any mechanical intervention : the flash of light on the photo-electric tube is amplified and acts on the lamps to transmit the signal.

A slot under the photoelectric tube is adjustable so as to correct the position of the flash at zero made when the signal is produced so that the readings may indicate surface depth instead of depth under the ship.

As there is only one transmitter-receiver, the scale is uniform in its whole length, no correction being necessary as in the case of a separate transmitter and receiver.

The apparatus gives 20 indications per second and sounds from 0 to 20 fathoms (36 m. 60). (Fig. 38 and 39).

XII. Echo-sounding apparatus using inaudible frequencies.

1° ULTRA-SONIC SOUNDING APPARATUS.

a) RECENT ULTRA-SONIC SOUNDERS S.C.A.M. AND MARCONI.

Piezo-electric properties of quartz.

In this apparatus, the piezo-electric phenomenon of quartz is utilised to transform electric oscillations into elastic oscillations.

This piezo-electric property of quartz was the subject of studies in 1880 by Pierre and Jacques Curie and in 1881 by Lippman. Mr P. Langevin applied this property to acoustic problems.

Piezo-electric properties are met with in certain crystals, for instance quartz, α, which is used and which in nature ordinarily appears in the form of hexagonal prisms, which is also the form of the perpendicular section thereof of which the three diagonals, which are at 120 degrees from one another, are three dyad axes of the crystal; they are called also "electric axes" on account of the phenomenon now under consideration.

If a sheet AB be cut from the crystal perpendicular to one of these electric axes, the thickness of which lies in the direction of a dyad axis XY and the surface contains what is called the triad axis of the crystal, it is found that if this sheet be compressed it will become electrically polarised although quartz is an inert substance. If two sheets of tinfoil be placed on the two faces, they form the armature of a condenser and if these two sheets be connected by a wire, when the plate is compressed it takes up what is known as an electric polarisation which causes the passage of a current in the circuit.

The electric charge A of polarisation is proportional to the pressure p exercised and to the surface S compressed with a coefficient δ called piezo-electrical modulus the value of which, for perfect quartz, was determined by Pierre Curie:

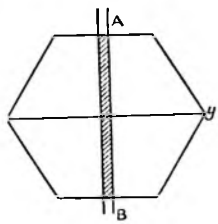
$$A = \delta \, p \, S$$

$$\text{et } \delta = 6{,}45 \times 10^{-8} \text{ C.G.S.}$$

If the combination so formed be compressed, the armatures will be electrified and a current in a definite direction will be obtained; and if the pressure be released a current in the reverse direction is produced. This is the direct piezo-electric phenomenon. The same arrangement can be used to detect the arrival of elastic waves; if the two armatures of the condenser are placed one in contact with the water and the other insulated therefrom and ultra-sonic waves reach them, the variation of pressure in the water periodically compresses the quartz and produces periodical currents. If a self-induction be inserted so that the period proper to the electric circuit is exactly the same as that of the incident waves, the current which tends to be produced will be amplified by resonance, and an electric oscillation will have been produced with ultra-sonic waves, due to the piezo-electric properties of the quartz.

This provides the means of direct transformation of elastic oscillations into electric oscillations in a circuit, and if the quartz condenser be tuned in accord therewith the resulting effect may be amplified (fig. 40).

Lippmann has shown that this phenomenon is reversible. If a difference of potential W is established between the two armatures of the condenser the plate of quartz will contract or expand to an amount in proportion to δ W. the modulus δ having the same value as previously. This fact remains correct in the case of an alternating difference of potential, and experience proves that by means of quartz an electric vibration can be transformed directly into an elastic vibration of same frequency.



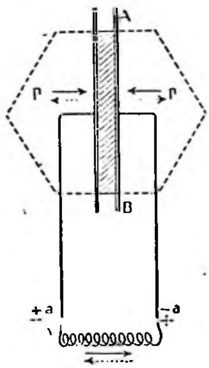


FIG. 40

The condition which appears necessary is that the magnitude of these contractions and expansions must be precisely of the amount of amplitude desired. This amplitude is obtained at departure by the following formula:

$$a_o^2 = \frac{P}{S} \frac{1}{\rho_o \ V_o \ \omega^2}$$

in which $\frac{P}{S}$ is the power given by square centimetre at the source, ρ_o is the density of water, V_o the velocity of sound in the water, and ω the pulsation of vibrations.

For 40,000 periods and a power given per square centimetre of 1 watt, the amplitude at the source is in the neighbourhood of 0.27 thousandth of millimetre.

The value of 1/3 watt/second per sq. centimetre is approximate to the maximum of the vibrating energy which water can transmit to the atmospheric pressure without breaking, that is without emitting vapour bubbles. This important phenomenon of the vibrating cavitation in the water, which is independent of frequency, places therefore a limit to the power emitted per sq. centimetre, which applies to all sub-marine generators of vibrations.

The figures are still much more surprising when that which happens at the return is considered and also that it is the same organ which serves both as a projector to emit the radiation and as an ear with which to perceive the echo sent back. When a signal or an echo is received, the amplitudes are very much reduced for they diminish in accordance with the law of the square of the distance; the amplitudes on return, which press on the quartz thus producing the currents which must work the amplifier, are of the order of 10^{-10} cms., that is to say a very good ultra-sonic reception must be available, for the molecules of water have movements the amplitude of which does not exceed one billionth of a centimetre, but by using the phenomena of resonance the difference of potential can be reduced to 3,000 volts which is admissible on board ship.

At the receiver arrangements are made so that the electric circuit containing the quartz has the same frequency of oscillation as the exterior excitement; thus an amplification is obtained which is in addition to that resulting from the use of the valve-amplifier.

For emission an elastic resonance is introduced. If a sheet of quartz of a certain thickness be taken, it will vibrate somewhat like a rod with a frequency in inverse proportion to its thickness; again if, when this quartz plate is excited by an alternating current

of a certain frequency, matters be so arranged that the elastic oscillation of the sheet shall be exactly in resonance with the exciting waves, the amplitude of the mechanical movements which the sheet takes up will be augmented.

Further, instead of obtaining the elastic resonance from quartz, it is procured from steel, and instead of utilising a thick sheet of quartz, Monsieur Langevin utilised a thin sheet of a few millimetres in thickness, and as big pieces are difficult to obtain, he built up a mosaic 10 cms. (4 ins) in diameter with pieces 2 to 5 m/m (0.1 in.) thick. (Fig. 41 & 42).

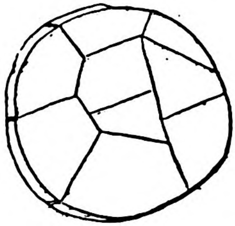


FIG. 41. — *Quartz Mosaic.*

This mosaic of quartz is stuck between two plates of steel, of which one forms the cover of the watertight box. The other steel plate is placed inside the box, insulated and in contact with the quartz and an opening is made through which passes the conducting cable connected with the other plate of steel. The whole of the interior can be filled with a more or less insulating thick mixture. These two plates of steel are each 3 cms. (1.2 ins.) thick, i.e. 6 cms. in all. The sandwich thus formed constitutes a compact solid of stone and steel without any movable organ which might have a period of vibration of its own.

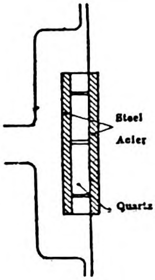


FIG. 42

If the resonance be commenced at the proper period, it is the total thickness which determines the half wave-length, and consequently, the power at which resonance is obtained.

This arrangement led to a very surprising and unexpected result, which was that, far from acting very much worse than with a fine piece of quartz, everything happened as though the steel itself had become piezo-electric.

If the quartz be thin in relation to the steel, the factor of amplification is :

$$m = \frac{\rho V}{\rho_0 V_0}$$

ρ is the density of metal allied to quartz, ρ_0 that of quartz, V is the velocity of sound in metal and V_0 the velocity of sound in quartz.

In view of the density of steel, this factor is equal to 25 approximately, so that in utilising this remarkable property an emitted energy 625 times greater is obtained with

the triple-ply with the same difference of potential. Where 60.000 volts were necessary, only 2.500 are required now, which corresponds to ordinary conditions of practice on board.

It is sufficient to excite the triple-ply with a voltage 25 times weaker than that required for a thick sheet of pure quartz.

Increase of power in emission is accompanied also by an increase of sensitiveness in reception.

For soundings, an ultra-sonic projector is used made of sheets of quartz placed between two steel plates of equal thickness h which form the armatures of the condenser.

One of these plates is in contact with the water, and the other insulated by a sheet of quartz, is charged to a varying potential at the desired frequency, for example by a triode valve acting as heterodyne.

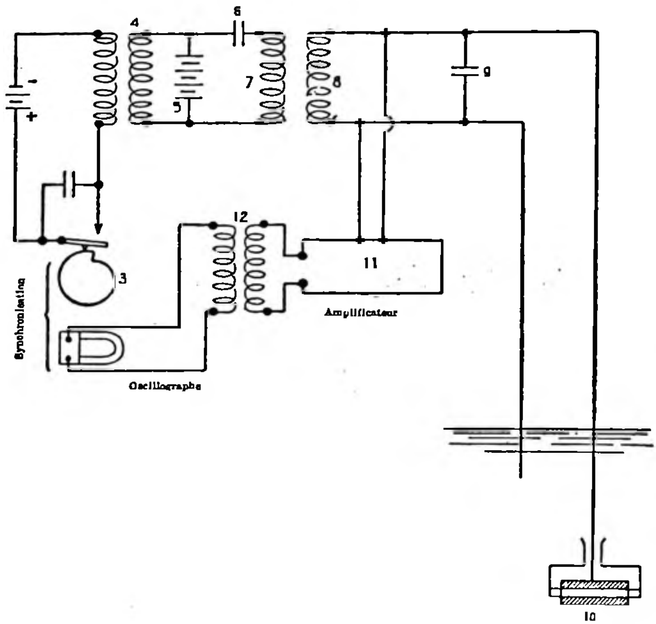


FIG. 43. — *Oscillograph Detector.*

If it be desired to produce waves of frequency N in the steel, then h must be made equal to one quarter of the wave-length in steel at this frequency.

Then the plates become resonant by pressing on each other through the sheet of quartz and the movements of the surface of plate B easily attain an amplitude of 10^{-4} $^{m}/_{m}$.

The ultra-sounds reflected by the bottom of the sea hit the projector, are transformed into electric oscillations which are increased by an amplifier and registered by an oscillograph. (Fig. 43).

Recent Ultra-Sonic Instruments.

Quartz ultra-sonic projectors.

The Langevin, S.C.A.M. or Marconi Ultra-Sonic Projector (fig. 44 & 45), appears as an iron box 6, the central part of the bottom of this being the outer vibrating armature of the piezo-electrical condenser. It is this surface which transmits the ultra-sonic vibrations to the water. The box contains a piezo-electrical plate of quartz 7 placed between

Fig. 44. — *Quartz Ultra-Sonic Projector.*

the outer steel plate 8 and the inner counterpoise plate 9; these two plates form the armature of the condenser. A highly insulated wire 10 crosses the neck of the Projector and connects the inner plate to the electrical transmitter with an earth return.

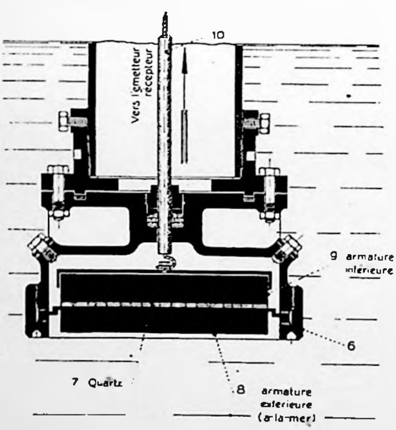
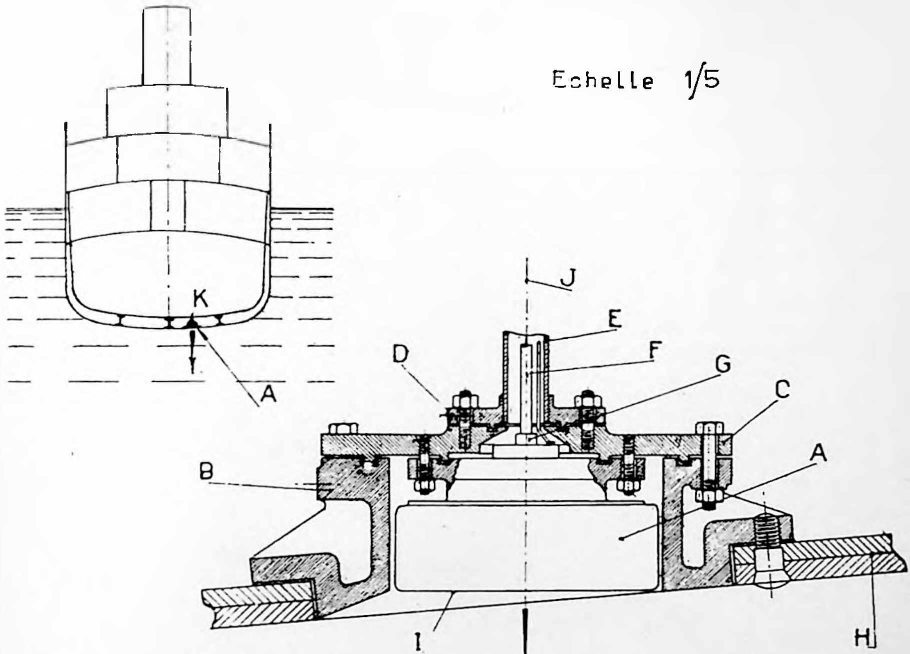


Fig. 45

The projectors have a diameter of 10 to 31 cm. according to the maximum depth to be sounded, as the power emitted is proportionate to the surface. They emit a sheath of conic-shaped ultra-sonic rays with an opening of approximately 12°, and the frequencies used are comprised between about 65,000 and 30,000.

Montage d'un Projecteur Ultra-Sonore de Sondage
sur la coque d'un navire de surface
accessible de l'intérieur du navire



A Projecteur U.S. Langevin type Sondage N°4
B Piètement en acier moulé
C Bride porte-projecteur
D Bride du tube-écran
E Tube-écran étanche
F Câble isolé allant à l'Emetteur-Récepteur
G Presse-étoupe du câble
H Tôle de bordé convenablement renforçée
I Façe émettrice du Projecteur [doit être horizontale]
J Axe de symétrie du Projecteur, vertical.
K Cale [accessible lors du démontage en cale sèche]

SCAM 296

Fig. 46. — *Fitting of an Ultra-Sounding Projector to the hull of a surface vessel with accessibility from inside the ship.*

A. Langovin ultra sonic projector - Sounding type n° 4
B. Cast-steel base.
C. Projector-bearer flange.
D. Protector-tube flange.
E. Watertight protector tube.
F. Insulated cable connecting with the Emitter-Receiver.
G. Cable stuffing-box.
H. Bottom-plating suitably reinforced.
I. Emitting face of the projector (should be horizontal).
J. Axis of symmetry of the Projector (vertical).
K. Hold (accessible for taking down in dry dock).

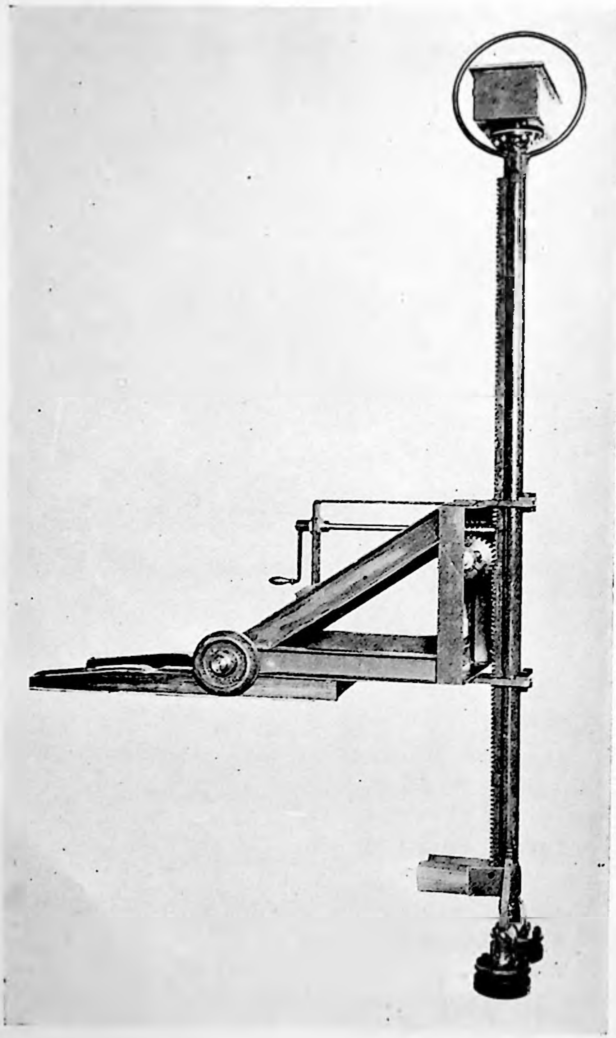


FIG. 47. — *Twin (Quartz-Steel) outboard bow fitting rotated on tracks to outboard position on bow.*

	Diameter of the transmitting plate.	Period of vibration proper per second.
(1) Projector S.4.ter (normal range 500 m. - maximum range 1,000 m.)............	220 m/m	37,000
(2) Projector S.7 bis (normal range 1,000 m. - maximum range 2,000 m.)..........	310 m/m	29,000
(3) Projector S.16, triple-ply, may be dismounted afloat, special for trawlers...	220 m/m	39,000
(4) Projector S.23, coastal type...........	100 m/m	65,000

The hull fitting by which the ultra-sonic projector is attached to the ship's side consists of a cast steel bed-plate secured in a watertight manner to the side plating by bolts or rivets. (Fig. 46). A tube, which also forms an electromagnetic screen against parasitic induction from the different electrical circuits on board, contains the leads running between the projector and the emitter-receiver. It forms a watertight conduit, protecting the cables from damp.

Figure 47 shows a twin (quartz-steel) outboard bow fitting rotated on tracks to outboard position on bow.

As the Projector is used for transmitting and receiving the echo, it is essential that the transmission of the signal be completed when the echo, as produced by the bottom of the sea, returns to the projector. When soundings are taken in shallow water, the time interval t, which separates the signal from its echo, is very short owing to the high value of the velocity of sound through water (i.e. $t = 1/100$ of a second at a depth of 7.5 metres (24.4 ft).

As soundings in very shallow waters are of extreme interest to navigation, it is necessary to use a very short ultra-sonic signal.

For this reason an emission consisting of a single train of damped ultra-sonic waves (fig. 48) is used. The duration of such a wave train (about 1/1,000 of a second) is very short in comparison with duration t corresponding to the smallest depth to be measured. This is produced electrically by means of an exciting pulsation Spark Transmitter which gives a single wave train for every signal.

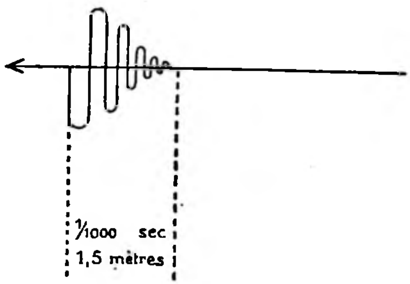


FIG. 48

Fig. 49 is a wiring diagram showing the principle of the electrical emitter and its connections with the projector and receiver and with the recorder.

The discharge circuit of the battery of accumulaors 39 consists of the primary 40, a transformer (induction coil) 41, and a special contact breaker 260 or 42, in parallel with a condenser 43.

The secondary 44 of the coil 41 feeds a spark circuit composed of a multiple discharger 45. the self-inductance exciting coil 46, and a condenser 47 (the positions of the discharger and the condenser may be exchanged indifferently).

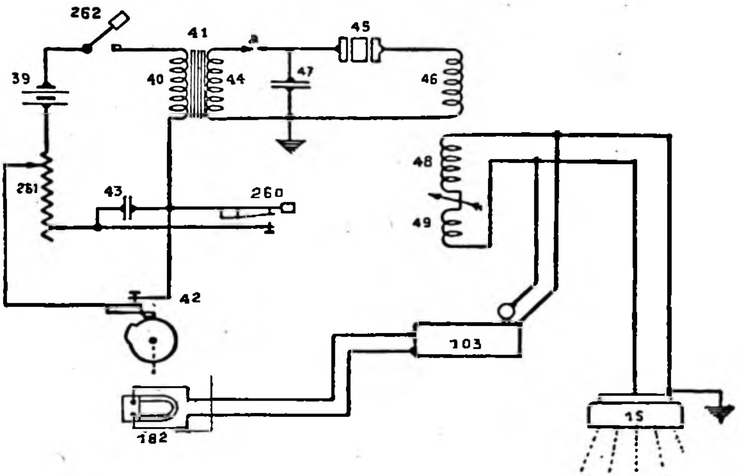


Fig. 49. — *Langevin-Florisson Ultra-Sonic Sounder - Electrical connections*

The fixed values L of this exciting coil and C of this capacity are adjusted at the factory so as to give approximately :

$$\frac{1}{N_o} = 2 \pi \sqrt{L.C.}$$

N_o being the frequency of mechanical resonance of the projector.

For the small projector (effective diameter 220 $^m/_m$).

$N_. = 37{,}030$ corresponding to $\lambda = 8{,}100$ m.)

For the large projector (effective diameter 310 $^m/_m$).

$N_o = 29.100$ corresponding to $\lambda = 10.300$ m.).

The oscillating circuit proper comprises the main self-inductance coil 48 coupled with the exciting coil 46, and an auxiliary self-inductance coil 49 (variometer) in variable coupling with the former, for adjusting the frequency of the train of waves and the piezo-electric condenser of the projector 15. This oscillating circuit is adjusted on board by means of the variometer, so as to get a proper frequency of electrical oscillations exactly equal to N_o for bringing into play the properties of mechanical resonance of the projector (Fig. 50).

On closing the contact-breaker 260 or 42, the current from the battery 39 flows in the primary of the induction coil 41.

On opening the same contact-breaker, either by hand (switch 260), or periodically at a set and automatic rhythm by the working of the recorder (chronograph, analyser, recorder, etc...), (contact-breaker 42), the battery current is sharply broken. A very rapidly growing electromotive force is set up in the secondary of the coil. When the difference of potential produced by the latter at the terminals of the spark gap 45 reaches the disruptive limit imposed by the size of the divisions of this multiple spark gap, the condenser 47 discharges in a few oscillations, thus inducing in the oscillatory circuit a single train of damped waves, lasting a matter of one-thousandth of a second, which is transformed by the projector into a train of ultra-sonic waves of the same form constituting the submarine emission signal.

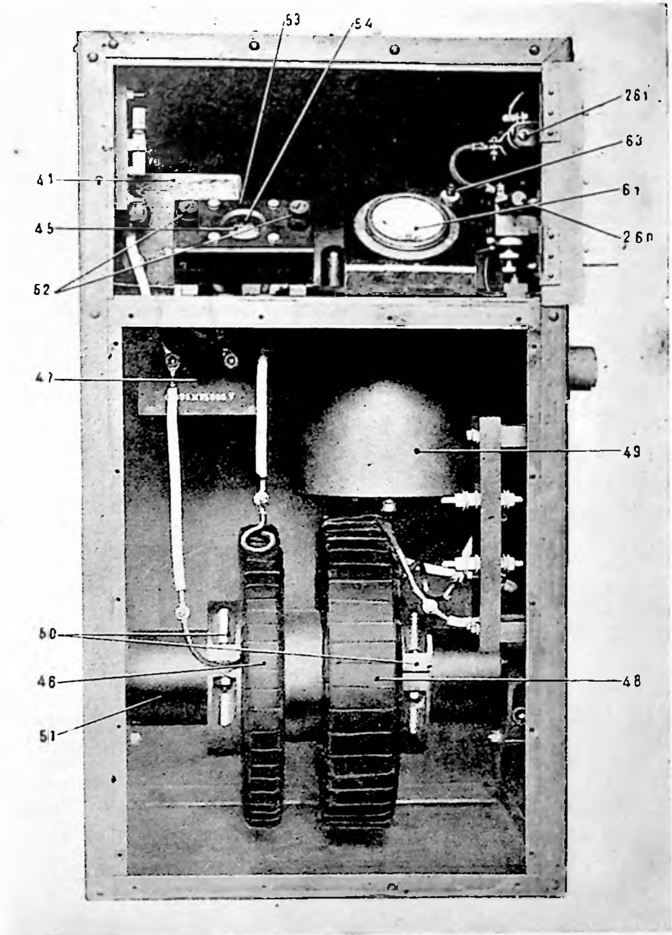


Fig. 50. — *Oscillating Circuit.*

In the case of sounding in very shallow water from small ships or boats, where only a small power is required, the emission can be obtained by the sudden discharge of a condenser charged by a battery of 80 volts in a choke coil coupled to the self of the oscillating circuit (fig. 51).

By means of an amplifier A connected permanently to the projector, the emission deviates a pen or a mirror mounted on the oscillograph O. Another deviation of the pen or mirror takes place by means of the electric oscillations generated in the oscillating circuit at the time when the triple-ply receives the train of reflected ultra-sonic waves.

The amplifier permanently connected to the projector, has been specially devised for transforming the short transmission and echo oscillating wave-trains into current impulses representing as faithfully as possible the enveloping contours of the corresponding oscillation wave-trains detected. This enables us to obtain by means of the optical or recording chronographic unit, in addition to soundings from depths of a few metres, a detailed representation (generally oscillographed) of the form of the echo.

The 7-valve amplifier, heated by 3-4 volts, must be fitted, from left to right, with :

1. — A special entry valve with highly insulated grid (the S.C.A.M. "lampe à corne" - horn valve), the filament of which in pure tungsten consumes about 0.7 amp. The horn grid must be connected by a supple wire, insulated by beads to the terminal P opposite (terminal on which is fixed the highly insulated cable leading to the projector).

2. — Five triode valves, type R.36. If it is desired to increase the sensitivity of the receiver, a T.A. 15 or A.415 valve might be substituted for the R.36 valve of the last stage but one.

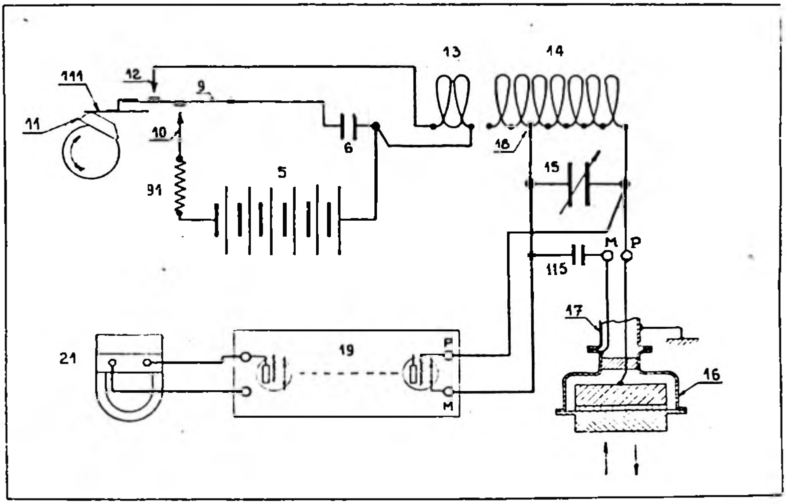


FIG. 51. — *Emission Circuits.*

3. — A low-frequency exit valve which must be :

a) When the sounding machine is fitted with an optical chronograph (Analyser, Indicator) : a T.A. 15 or A.415 valve. In this case the tension of negative polarisation of the grid of this valve must be selected experimentally usually in the neighbourhood of — 4 volts.

b) When the sounding machine is fitted with a Langevin-Touly electrolytic recorder : a penthode B.443 valve. In this case the tension of negative polarisation of the control grid of the valve must be selected experimentally, usually in the neighbourhood of — 13 volts. The accelerating grid of the penthode must be connected to the + 80 v.

Emission by sonic impulse of short duration, for example 1/1,000th of second, represents a wave train of 1 m. 50 long, owing to the high velocity of sound in water. A Japanese engineer, Mr. Sadahiro Matsuo, had the idea in 1937 of substituting for the emission by impulse, a permanent modulated emission and at the time of reception, he observed the phenomenon of beatings due to the interference between the direct wave and the reflected echo wave, obtaining thereby a continuous indication of depth. Although

detection in this way is difficult. it has been possible by this method to find clearly shallow water of a depth of 15 centimetres, under the face of the projector, in the port of Shiogama on board a pilot boat.

The oscillograph is a sort of ballistic galvanometer, very sensitive, with magnet, inductor-alternator and stationary field-winding. It comprises, as a rule, a permanent magnet, between the poles of which can oscillate a soft iron blade. When a short current passes through the coil, the movable blade pivots around its axis and forms an angle in accordaance with the intensity of the current before returning to its original position; it thereby moves either a mirror or an inscribing stylus.

The magneto-oscillograph Abraham-Carpentier, sketches of which appear in fig. 52 and 53, is particularly suitable for graphically recording ultra-sonic soundings on smoked paper, at very shallow depths; the moving element has very little inertia. The torque of the motor is sufficiently strong to enable the needle easily to overcome the friction on the smoked paper.

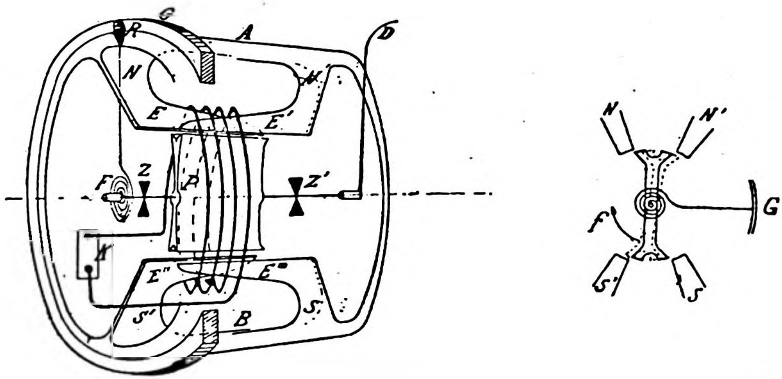


Fig. 52-53. — *Abraham-Carpentier, Magneto Oscillograph.*

The cylindrical permanent magnet A (imagined to be transparent in the figure for the sake of clearness) has its field concentrated towards the axis by four radial poles N, N', S, S', grouped in pairs at opposite ends of two diametrical planes of the magnet. Between these poles can oscillate a soft iron blade P.

If no current is flowing in the exciting winding, the movable blade is in stable equilibrium under the action of the two opposite fields of the pairs of poles N-S and N'-S' (as shown by full lines in fig. 53).

If a current is flowing in the winding in a direction such that its field is opposed to that of N-S and in accord with that of N'-S', the blade pivots around its axis in the direction of the arrow f to a new position of equilibrium (broken line).

The amplitude of the swing of the blade, and so of the needle, is a function of the intensity of the current in the coil.

The Dubois Oscillograph (fig. 54), is more especially used for the optical detection of signals and echoes.

This oscillograph is a sort of galvanometer with mirror, very sensitive, with magnet, inductor-alternator and stationary field-winding, with very rapid and at the same time periodical movements. Figure 54 shows the oscillograph with open cover. Figure 55 is a diagrammatic representation of the instrument.

The movable element of the oscillograph has a natural mechanical oscillation frequency of the order of about 1,500/sec. The instrument is made aperiodic, which is necessary for the faithful oscilloscopy of sounding pulsations, by introducing, at the factory, a drop of Thick oil (Mobiloil C) between one of the faces of the blade (47) and the opposite side of the tubing which contains the latter.

A coil receives the current to be detected by the oscilograph, i.e. the impulse corresponding to signal and echo. This current magnetises the armature 40, which will obviously turn on its axis, thereby rotating the shaft which carries a small concave mirror 39 on which impinges a beam of light, so that the beam will be deflected in proportion to the rotation angle of the mirror, i.e. in proportion to the current in the coil.

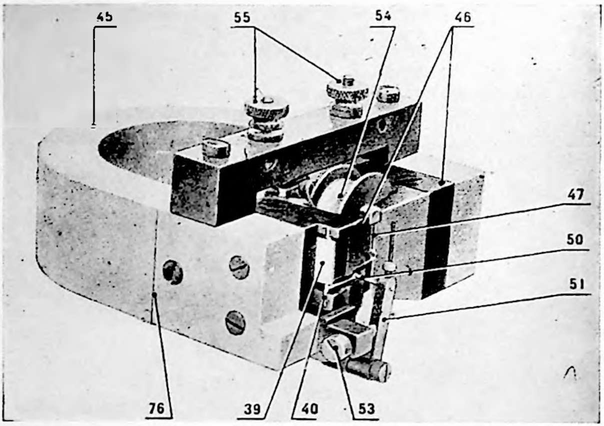


FIG. 54. — *Dubois Oscillograph.*

The mirror 39 throws a real image of the spot of light on the screen, so that the motion of the armature is shown by the displacement of the real image on the screen.

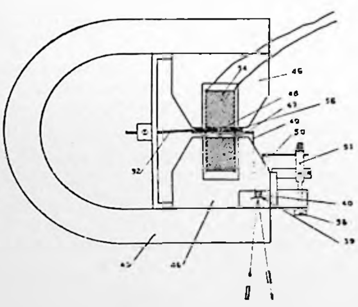


FIG. 55

Owing to the introduction of oil, the movement is rendered aperiodic and is reduced to a half-oscillation or echo indentation.

b) RECORDING APPARATUS.

Marti Recorder.

(See also: *Hydrographic Review*, Vol. II, N° 2, May 1925, p. 145; Vol. III, N° 2, July 1926, p. 89; Vol. XI, N° 2, Nov. 1934, p. 51).

The recorders used are either ink or smoked paper, or electrolytic recorders.

The ink or smoke paper type (Marti apparatus) comprise a constant speed motor M (fig. 56) controlled by means of a centrifugal governor r, which introduces resistance R as soon as a definite speed is exceeded and rotates, by means of an endless screw fixed onto the shaft, a wheel to the axle of which is attached an arm B, which carries on one side an extremely sensitive oscillograph O and on the other side a counter-weight p. The arm B rotates at a speed which varies according to the number of soundings required per second and according to the recorders used. The rotation is on a vertical plane for the smoked paper recorder and on a horizontal plane for the ink recorder (see figure 18, page 32 above). A recording strip of smoked or glazed paper moves below this plane, on which the stylus of the oscillograph draws arcs of circles. The wires of the oscillograph are connected by means of two concentric rings on the wheel of the arm B, and by the corresponding brushes with the amplifier A. Thus a current passes through the oscillograph both when the sound signal is emitted and when it returns and this causes the stylus to deviate. The arcs drawn by the stylus show peaks at emission and return of the sound waves, and the distance separating the initial points of these deviated peaks is obviously in proportion to the elapsed time and consequently to the depth of water.

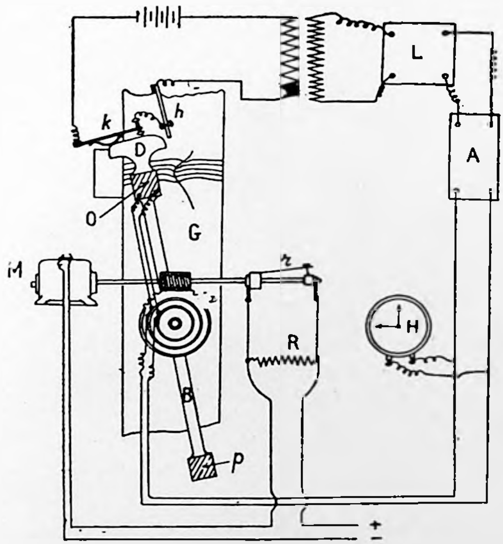


Fig. 56. — *Diagram of Marti apparatus.*

The cam D by acting on the double contact H and K causes the emission of the sound at the exact instant when the stylus of the oscillograph is on the edge of the recording strip; when sounding in great depths the emission may be advanced by a definitely determined space of time, in order that the second indentation shall always fall on to the recording strip.

By joining the initial points of those indentations which were produced in the record by the reception of the echo by the oscillograph, a profile of the bottom of the sea is obtained and the depth can be deduced therefrom (fig. 57).

The strip of paper is divided into depths of water by suitably spaced parallel lines; the origin of the division coincides with the right hand side of the initial peaks. It is therefore possible to read immediately the depths on each point of the wavy line of echo teeth.

Various types of recorders exist, giving soundings every 7.5 seconds in the exploration type, every 3 seconds in the navigation type, and every 1.5 and 0.5 second in the two hydrography types. It is thereby possible to register on the recording strip teeth echoes corresponding to depths of 500 m., 200 m., 100 m. and 30 m.

It may happen, under certain circumstances, that the emission takes place before the stylus reaches the graduation on the strip. Each of the successive displacements, amounting to 9, corresponds to the total breadth of the graduation, and in this way the recorder can be utilised for depths ten times greater than previously.

Further, an adjusting screw enables the position to be regulated to get the zero exact i.e. to make it coincide exactly with the first nick made on the record at the moment of emission of the sound wave.

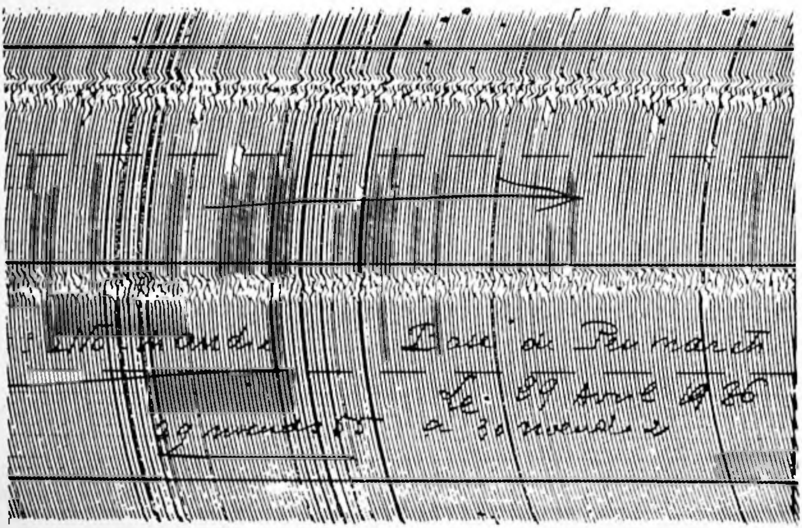


FIG. 57. — *Record of ultra-sonic soundings on board the "Normandie".*

There is an arrangement for reducing the number of soundings taken normally by the machine which gives three modes of working :

(1) Continuous working, in which this device is short-circuited the striker acts at each turn of the recorder.

(2) Periodic working, in which the striker only acts at every fifth turn of the recorder.

(3) Slow-motion working, in which the striker only acts at every twentieth turn of the recorder.

Finally, to allow the operator to make the emission nick appear whenever he requires it to do so, a press-button with recall spring, marked "Réglage du zéro", is placed on the upper panel of the machine.

It is of course the beginning of the nick marking the echo which gives the depth reading. In the same way the departure of the emission corresponds to the beginning of the signal nick.

French hydrographic vessels have utilised for the last 18 years recorders with smoked paper and more recently recorders with ink.

Langevin-Touly electrolytic recorder.

(See also: *Hydrographic Review*, Vol. XIII, N° 2, Nov. 1936, page 110; Vol. XIV, N° 1, May 1937, p. 111; Vol. XV, N° 2, Nov. 1938, p. 35).

The electrolytic recorder, Langevin-Touly system, differs from the preceding one in that it does not comprise an oscillograph.

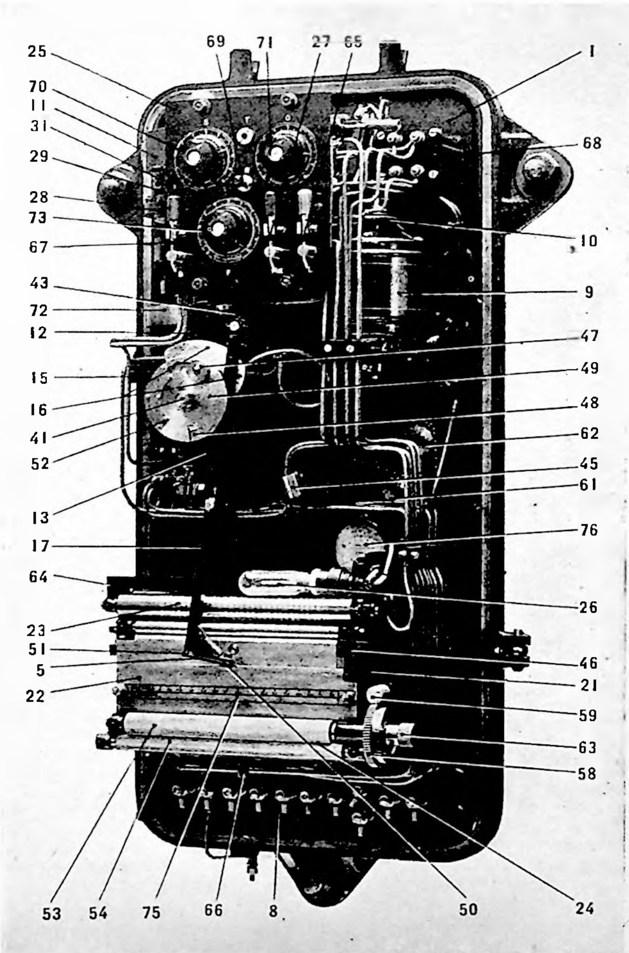


Fig. 58. — *Langevin-Touly. Electrolytic recorder - Cover removed.*

There is used a band of moist electrolytic paper, which unrolls slowly from top to bottom. This band is supported on a metal surface which is connected to the negative pole of the circuit leading from the amplifier. In front of the paper a metallic stylus is carried by a moving arm. By means of a suitable cam, the arm describes the arc of a

circle from left to right, transverse to the band, at a pre-determined speed, returning rapidly to the position of rest at the left. The same movements are repeated periodically. The stylus is connected to the positive pole of the circuit leading from the amplifier.

At the beginning of the movement of the stylus across the band a second cam releases the ultrasonic emitter by means of an interrupter. Thereupon the current coming from the amplifier passing through the stylus to the metal plate through the moist paper electrolytically decomposes the salts with which the paper is impregnated and leaves a brown mark on the paper. With each arc described by the stylus one sees the first mark on the paper corresponding to the instant of emission of the signal and a second mark given by the echo of the signal. As the paper slowly unrolls, the beginnings of the echoes successively traced on the paper, show the profile of the ocean bottom at a scale depending upon the speed of the vessel. An interrupting device electrically insulates the stylus during the time it is returning to its zero position.

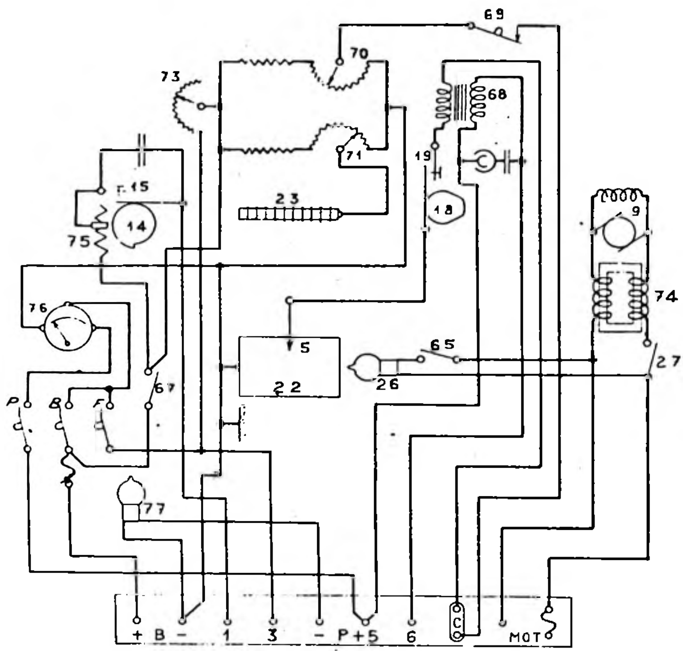


FIG. 59. — *Diagram of the Electrolytic Recorder.*

In order to facilitate the depth reading, a cylinder with disks marked at equidistant intervals presses against the moist paper and marks by electrolysis the lines corresponding to each 10 metres' depth.

The breadth of the recording strip is 160 m/m and the whole of the breadth of the strip is graduated from 0 to 300 metres.

In the most popular model of recording device, the soundings are made every 3 seconds and the paper unrolls in such a manner that the arcs of the successive circles are spaced 0.75 m/m apart. The unrolling rate is 90 cm. per hour. By means of a copying stylus one can mark on the record any note or information desired (such as the hour, position, etc...) without stopping the operation of the device.

A large magnifying glass located outside permits one to read the soundings more closely if desired.

The sharpness of the echoes and the distinctness of the marks obtained is due in this case to the fact that here there is no vibratory movement of the pen of the oscillograph.

Each roll of paper provides for an operation of about 40 hours. The band unrolls at a rate of about 90 cm. (36 inches) per hour.

Fig. 58 & 59 show the diagram of the apparatus. At the top on the right is the electric motor 9 (generally a 7-volt motor operating on a storage battery of 8 volts) and the centrifugal speed regulator 11. The constant speed shaft of this motor drives through reduction gear comprising a pinion and tangent screw, and cam and the emission interrupter 19 the cam 16 and the oscillating arm 17 with the stylus 5.

At the top of the paper are the various devices : 67 is the switch for starting and stopping; 27 the switch of the motor; and 56 the switch for the illuminating lamp. The potentiometer of the stylus 70 provides the stylus with a small positive potential which is adjustable so that the stylus may leave a faint trace on the paper of the arc described, thus facilitating following the signal to its corresponding echo. A marking button for the hours 69 is provided so that a slight mark can be made when the button is pressed which serves as an indication on the diagram when no written memorandum is made. The potentiometer 71 of the marking cylinder, indicating the depth markings, can be adjusted as desired in order to regulate the intensity of these graduations on the paper band. Finally, at 73 is the rheostat for the adjustment of the sensitivity of the instrument. This is actually the heating rheostat of the receiving amplifier.

At 52 is the device for changing the zone of the recording apparatus. By means of a locking screw 47 the inscription cam is shifted with relation to the emission cam so that the angles correspond mechanically to the successive multiples of 300 metres.

The cam which carries the arm for the stylus may easily be shifted in phase with regard to the emission so that successive positions of the setting permit the recording of depths between the minimum limit of the order of 3 to 5 metres up to 300 metres; 300 to 600 metres etc., up to the maximum range of the echo of the sounding apparatus.

This recorder is fitted with a stroboscope to check the speed and a regulator for correcting the draught

The new recorder type 439 takes 90 soundings per minute. Two scales are provided, one 0-75 fathoms. and one 70-145 fathoms. by having an extra sounding contact set to transmit an appropriate interval before the arm starts.

c) ECHO-SOUNDERS WITH OPTICAL INDICATORS

Optical analysers can be utilised in place of the recorders.

Langevin-Florisson Optical Analyser.

(See also: *Hydrographic Review*, Vol. III, N° 2, July 1926, p. 75; Vol. V, N° 2, Nov. 1928, p. 107).

In the Langevin-Florisson optical analyser (fig. 60, 61 and 62), a vertical ground glass plate 19 is divided according to the depth with a definite scale; along this plate a luminous point, to which a uniformly straight motion is given, runs vertically from top to bottom, and taking the fact into account that the ultra-sonic wave train runs twice the distance from the Projector to sea bottom, its velocity equals half the velocity of sound through water at the scale of the divisions.

The chronographic device which produces the uniform motion of the luminous point starts the ultra-sonic emission when this point passes the zero of graduation, or rather, passes the number on the scale which corresponds to the depth to which the Projector is immersed, which allows the correct reading of the depth as measured from the surface of the sea. This is indicated to the observer by the appearance of an indentation 20 in the luminous path.

As the echo returns, the luminous point undergoes another lateral displacement which shows a new indentation 21 on the scale. The distance d separating the origin of the two indentations 20 and 21 represents the depth which the observer can read directly opposite the origin of indentation 21.

The above described operation refers to a single sounding.

The Analyser automatically repeats this operation once per second, therefore it permanently shows the actual depth of the sea beneath the ship.

The constant speed of the luminous point is obtained by means of the arrangement shown diagrammatically in figure 62.

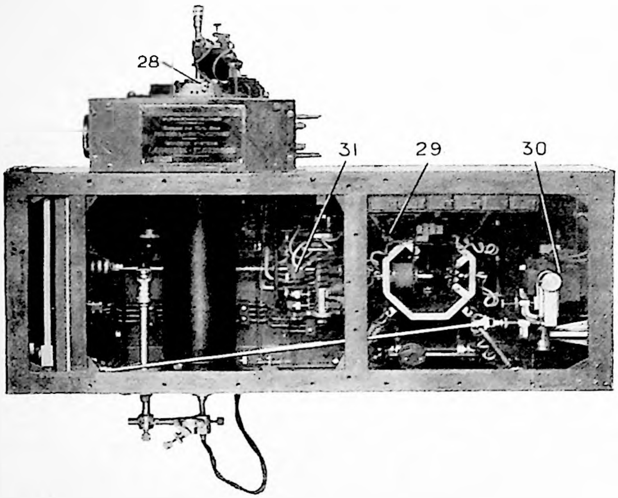


FIG. 60. — *Langevin-Florisson, Optical Analyser.*

The rectilinear filament 22 of an electric lamp is placed along the axis of the opaque cylinder 23, in the wall of which is pierced an helicoidal slit 24, which makes one complete turn round the cylinder. A concave mriror 25 throws a luminous point 26 on the transparent scale 19, i.e. the image of the point of the filament 27 seen from the summit of mirror 25 through the slit 24.

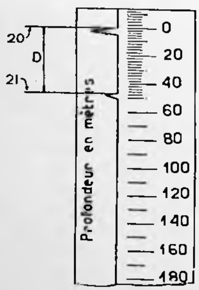


FIG. 61

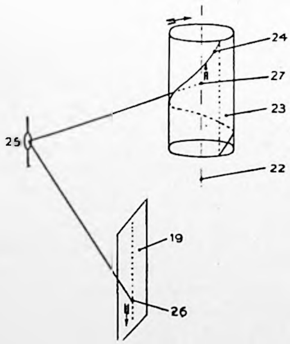


FIG. 62

Cylinder 23 is moved round its axis with a uniform motion by means of a special small synchronous electric motor, fed by continuous current which is cut off at exact intervals by means of a special tuning fork, the "Guéritot Ticker". This motor, once in step, maintains an absolutely constant speed. No error can occur, because either the motor turns at

this exact speed or else it is stopped. Consequently a rectilinear displacement of the luminous point at constant speed is produced (chronographic motion of the apparatus).

The axle of the governed electric motor drives, in addition, a special interrupter, which starts the ultra-sonic emission at each of the successive passages of the luminous point over the zero of the graduation, as mentioned above.

Mirror 25, which produces the luminous point, is part of an extremely sensitive oscillograph, suitably damped, which is permanently connected to the Receiving Amplifier. When the emission and the echo are produced, the latter is subjected to a slight displacement about an axis parallel to the axis of the cylinder 23. This shows the indentations 20 and 21, indicated above on the path of the luminous point on the scale 19.

The Phonic Motor 28 governed by the "Guéritot Ticker" 29, the Oscillograph in its adjustable mounting 30, the Automatic Switch 31, and the various parts for adjusting and controlling the Analyser will be seen in the figure.

The most recent quartz sounding machines are the Langevin-Florisson ultra-sonic sounding machines, fitted with echo-meter or echoscope. They are manufactured by the Société de Condensation et d'Applications Mécaniqres and also by the Marconi Company.

Langevin Florisson Echometer.

(See also: *Hydrographic Review*, Vol. VII, N° 2, Nov. 1930, p. 105; Vol. X, N° 2, Nov. 1933, p. 168; Vol. XI, N° 2, Nov. 1934, p. 58).

The echo-meter (fig. 63 & 64) contains, in a single metallic case, the transmitter, the receiver and analyser. The high-frequency emitter, which consists of a small spark installation (radio-telegraphic type but extremely simplified) and the receiver (valve amplifier), are contained in the lower section of the case.

The analyser is contained in the upper section of the case.

Fig. 63 shows the exterior appearance of the Echometer. The number 43 indicates the scale on which readings are made and this is usually graduated from 0 to 660 metres (361 fms). The magnifying glass 176 makes the "teeth" more easy to distinguish. The starting and stopping of the apparatus is worked by the plug 93, and 143 is the winding stem of the movement; the rheostat 57 controls resistances in the oscillograph circuit thus making it possible to reduce its sensitiveness in shoal water and the milled head 71 governs the height of the luminous spot. In the 660 metre model soundings are taken automatically every 7/6 second.

Fig. 65 shows a diagrammatic arrangement of the upper part of the apparatus as seen from above, the lid being removed. The graduated scale is marked P. A diaphragm H is brightly illuminated by an electric lamp G. The pencil of light is reflected by two prisms I and J, then by the mirror K of the oscillograph and finally by a plane mirror L. A small, sharp and brilliant image N (the spot) of the diaphragm H is thus produced on the scale. The mirror L is not fixed but swings at a constant angular velocity about the axis L and thus the spot traverses the scale at a constant velocity from left to right. When the spot has completed its run, the swinging mirror L comes sharply back to its initial position bringing the spot back to the zero of the graduation after each sounding.

Fig. 66, shows the mechanism which causes the displacement of the spot N at a constant velocity along the scale P. The mirror L is attached to a sector Q which can move about the vertical axis R. A steel wire, stretched by the spring S, is provided with a small bar T at right angles to the wire. The ratchet-wheel U revolves, by clock-work (not shown), at a rigorously constant speed. A tooth of the ratchet-wheel catches the bar T and carries it with it thus causing the mirror L to turn about the axis R at a constant speed. This motion continues until the ends of the bar T reach the inclined fork V which lies astride the ratchet-wheel. This throws the bar clear of the tooth and, owing to the action of the springs shown, the sector Q springs back until it reaches a stop (not shown). Owing to this, the spot is brought very sharply back to the zero of the scale graduation. The cycle is repeated as soon as the next ratchet tooth catches the bar.

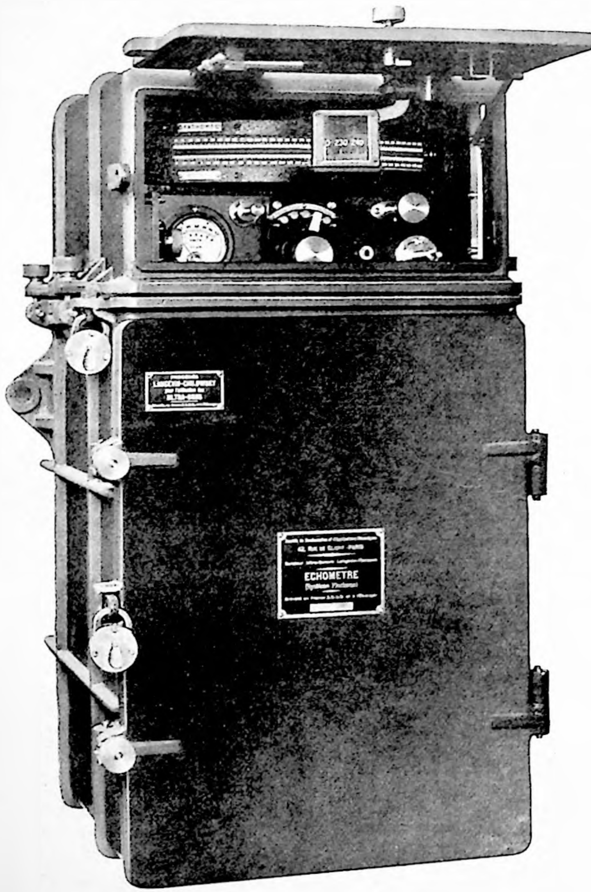


FIG. 63. — *Langevin-Florisson Echometre.*

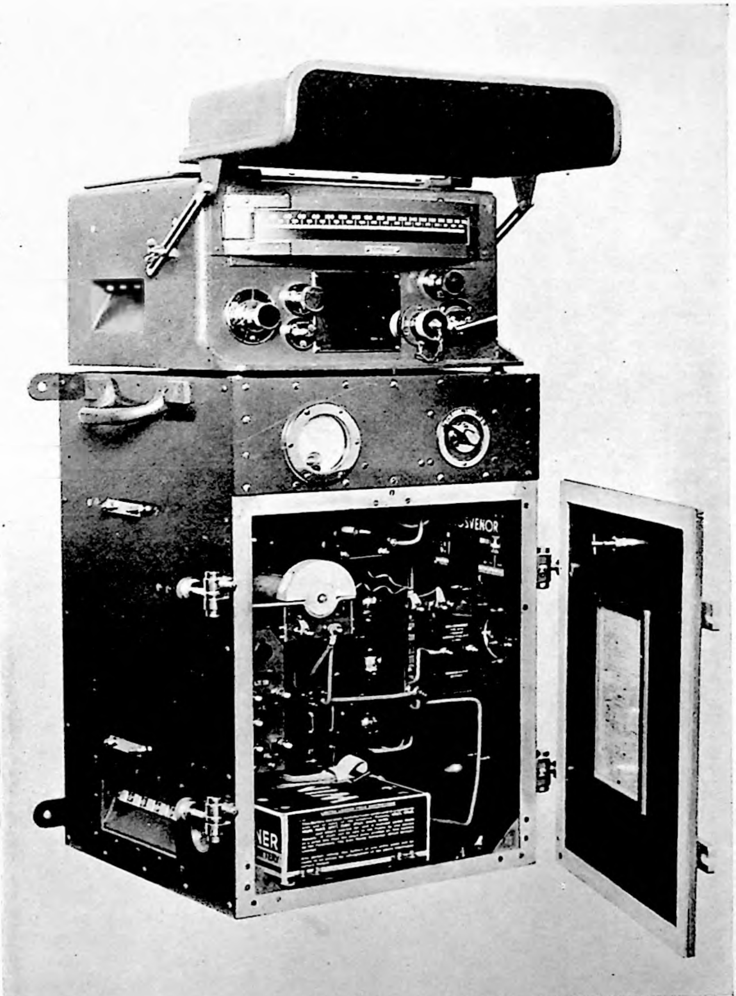


Fig. 64. — *Langevin-Florisson Echometre.*

An appliance (not shown), which causes the ultra-sonic emission when the spot passes the zero of the scale, is attached to the sector Q.

An accurate centrifugal governor assures constant speed. A complete winding of the movement gives about 10 minutes of constant speed. The normal speed is one turn of the ratchet-wheel in 7 seconds, and as this wheel has six teeth there are six soundings every seven seconds. The apparatus is started by pulling the knob 146 of the clockwork (fig. 67 & 68). A telephone jack 167 enables the operator to listen to the signals and echoes with earphones.

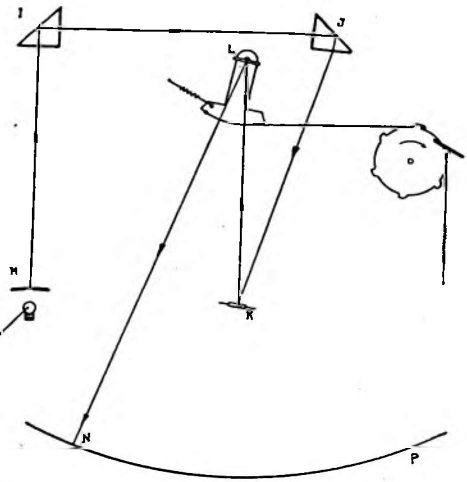


FIG. 65

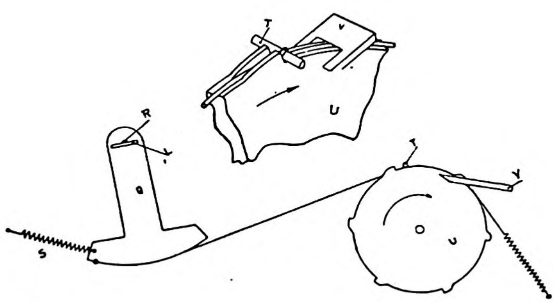
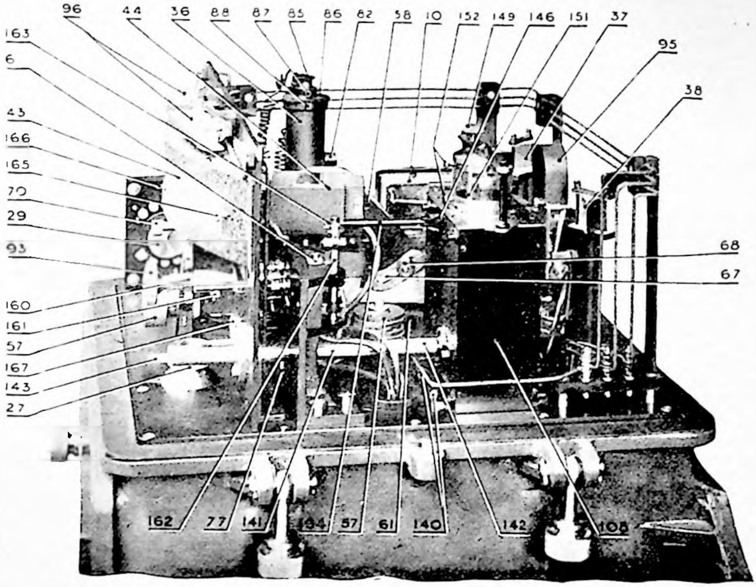


FIG. 66

The new type 421 instruments differ slightly from the previous type 414, in the control system and in the path of the light ray of the optical system, the prisms of which have been abolished. They include also a new control knob which governs the sensitivity of the instrument, i.e. the size of the nicks in the signals appearing on the scale.



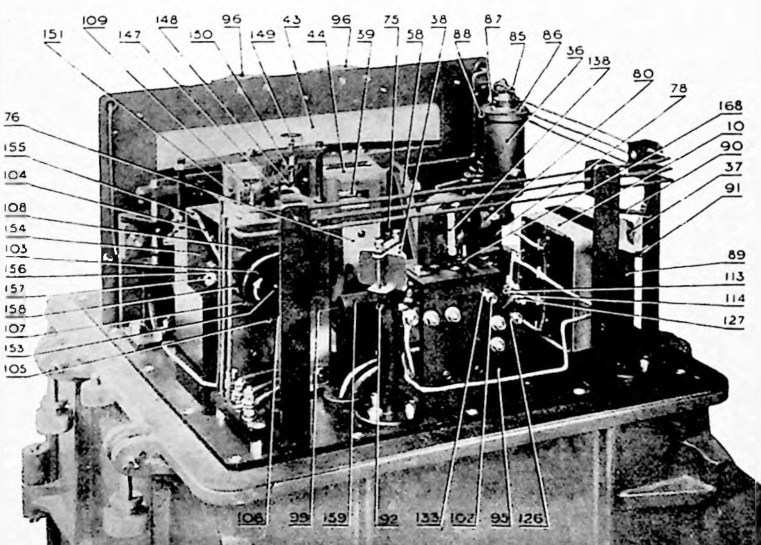


FIG. 67-68. — *Langevin-Florisson Echometer interior views.*

The machine takes approximately one sounding per second. and readings can be taken from about 3 metres (1.6 fms.) below the face of the projector to depths of 660 metres (361 fms).

This machine can also be used in conjunction with an electrolytic recorder.

In the case of the indicator, a great deal of information can be obtained by watching the shape of the echo peak. When working under normal conditions the echo peak is usually about one-third of an inch high. Its left-hand is practically vertical, its right-hand edge sloping down steeply, as indicated in fig. 69 a.

The echo peak will only assume this form when the sea bed is firm and reasonably smooth, being free from rocks and large boulders.

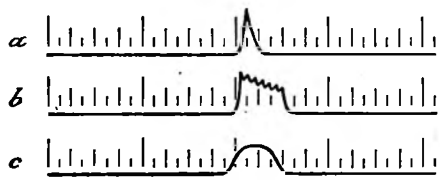


FIG. 69

a) Shape of normal echo peak.

b) Echo peak over boulders and rocks.

c) Echo peak over very soft mud.

If the sea bed is covered with rocks and boulders, the echo peak takes a distinctive form which can be recognised very easily. Its left-hand edge is practically vertical, but instead of its right-hand edge sloping down sharply, it comes down slowly in a sort of saw edge, as shown in Fig. 69 b. This difference is very clear and well marked and can be noticed at a glance.

Further information can be obtained by watching the peak more carefully. If it is wider at the base than usual, but otherwise normal, it indicates a very soft bottom ; ooze or soft mud as shown in fig. 69 c.

If the bottom is shelving very rapidly the echo peak appears its normal shape, but smaller; that is to say the amplification has to be increased to bring the peak up to its normal size.

Langevin-Florisson Echoscope.

(See also: *Hydrographic Review*, Vol. X, N° 2, Nov. 1933, p. 170; Vol. XI, N° 2, Nov. 1934, page 59; Vol. XV, N° 2, Nov. 1938, pages 44 and 51).

In the Echoscope, which is meant more especially for soundings in shallow water (fig. 70). a diaphragm 71 (fig. 71) is brightly illuminated by the electric lamp 73 with reflector 77. The pencil is reflected by the mirror 39 of the oscillograph and again by the spherical mirror 36 which turns at a constant speed about the axis 37. The scale 38 being centred on the axis, the spot moves along the scale at a constant speed from left to right, the plane of figure 71 being here a vertical one.

The left-to-right constant speed movement of the luminous point on the scale enables the "echo interval" to be measured.

The movement of the luminous point on the scale is thus repeated at every revolution of the axis of the clockwork device carrying the mirror, and emission is produced by a cam at the time when the spot passes the zero of the graduation.

Fig. 70. — *Langevin-Florisson Echoscope.*

The brief antero-posterior displacements of the luminous point on the scale, constituting the "tooth", which occur without any lag at the instant of the transmission and of the echo, are caused by slight and brief angular displacements of the Dubois oscillograph mirror turning about a horizontal axis; this oscillograph is permanently connected to the amplifier which in turn is permanently connected to the projector.

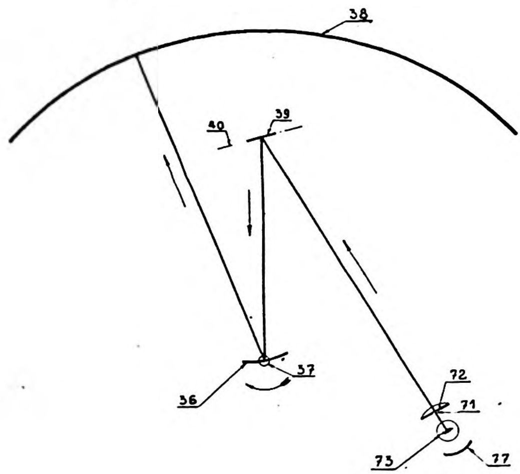


FIG. 71

A jack is provided for telephonic transmission.

This portable apparatus weighing about 50 kilos is principallj used for inshore hydro-the projector, and the scale is graduated to 60 metres (33 fms). Soundings are taken every 10/11 of a second, and one winding of the clockwork gives about 15 minutes of working.

This portable apparatus weighing about 50 kilos is principally used for inshore hydrography and for soundings from small boats of 1 m. 20 to 60 metres.

SCAM.-Touly Indicator.

(See also: *Hydrographic Review*, Vol. XI, N° 2, Nov. 1934, p. 46; Vol. XIII, N° 2, Nov. 1936, page 107; Vol. XV, N° 2, Nov. 1938, page 33).

In the *SCAM-TOULY Indicator* (fig. 72 & 73 a & b), the device for reading the echoes consists of a neon lamp ; this lamp has the property of lighting up and "blacking out" very quickly.

The neon lamp 21 is mounted horizontally on the prolongation of the geared shaft of the motor. As this shaft revolves at constant speed, it carries and drives by its rotation, not only the system of cams which produces the emission at each rotation, but also an arm 28 on which are mounted a small tilting mirror 66 and a lens 67. This rotating optical system produces a reduced image of the luminous part of the lamp in the transparent circle between the two sets of graduations of the indicator. When the optical system rotates, the image of the lamp moves and a circle of light appears between the two graduations.

The method of mounting the optical system with respect to the emission cam is such that the departure of the elastic wave train occurs when the left-hand edge of the image of the lamp passes through the zero of the graduation. At he same time, the neon lamp is

extinguished and put back into circuit at the proper moment by the contact 52 or 53 (according to the amplification). During the interval between the departure of the signal and the return of the echo, the neon lamp is extinguished and the optical system continues to turn. When the echo arrives, it lights the lamp, the image appears and occupies on the graduated scale a position different from that which it had at the moment of departure. The image continuing to turn gives the impression of a luminous arc. The place where the image of the lamp begins to appear indicates the required depth on the scale, which is suitably graduated.

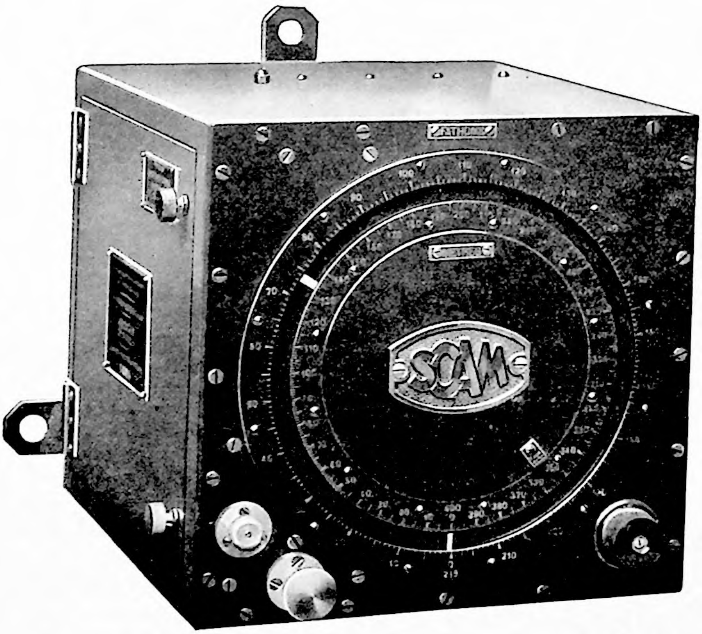


FIG. 72. — *Echo sounding indicator Scam-Touly type.*

The graduation of the scale having been established once for all, the speed of rotation of the optical system must remain constant and accurately determined during the soundings. This speed has been fixed at one revolution per second.

The speed of 2,400 r.p.m. of the shaft of the driving motor corresponds, when geared down, to the above speed.

Use is made of a shunt motor fed from the 12-volt battery. The speed of this motor, which is thus supplied at constant voltage, remains constant for practical purposes and can readily be regulated to the figure of 2,400 r.p.m. by a rheostat in series with the armature. A sturdy belt-driven centrifugal tachymeter shows the speed at which the motor is turning by means of a needle moving over a quadrant. To read the exact depths on the graduation of the indicator, it is only necessary previously to bring the needle of the tachymeter on to the 2,400 mark, which is a stronger and longer line than the remainder; this is done by setting the adjusting rheostat.

As an exception, where the velocity of sound may be very different from the normal value of 1,500 m/s (4,921 ft/s.), the correction can be made automatically by running the

motor at a speed which is to 2,400 as the true velocity of sound is to 1,500. The conversion table is as follows :

Velocity of sound	Speed of motor
1440 m/s.	2304 r.p.m.
1460	2336
1480	2368
1500	2400
1520	2432
1540	2464

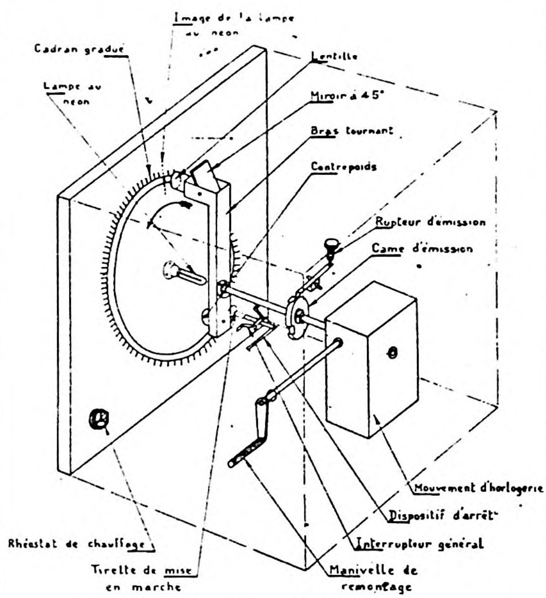


Fig. 5 - Disposition schématique de l'Indicateur SCAM Touly.

FIG. 73 a

The motor is constituted by a robust clock mechanism making 15 turns in 8 seconds. A handle to one side, at the right, is furnished for winding up the mechanism, each winding providing for an operation of about 10 minutes' duration.

The neon lamp is secured behind the dial and in the axis of the graduated circle.

The dial is graduated around the entire circumference. Thus the indicator provides for the possibility of reading equally the depths comprised between 400 and 800 metres.

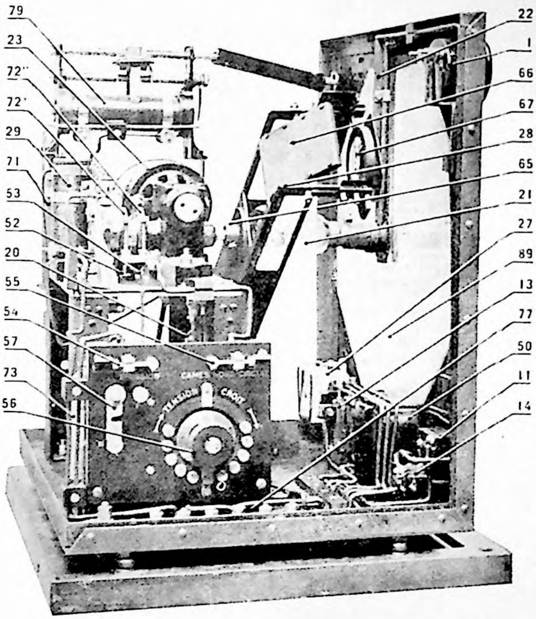


Fig. 73 b

The reading of the echoes is facilitated by the push-button switch located at the bottom and to the left of the dial which allows the emission to be suppressed as desired.

The apparatus is started and stopped by means of a push button located to the left and below the dial. This button releases the rotating arm and closes the main switch of the sounder.

The neon lamp is supplied by a dry galvanic battery, well insulated, of 220 volts.

2° MAGNETO-STRICTION ECHO-SOUNDERS.

GENERAL.

Magneto-Striction Oscillators.

Many magnetic materials exhibit the property of varying their lengths when subjected to a magnetic field, (the Joule effect) and conversely of changing their magnetic condition when mechanically strained (the Villari effect). These properties have formed the subject of research in a wide range of alloys, especially the alloys of iron, nickel and cobalt.

For instance iron actually increases in length for low magnetisations and then completely reverses and decreases in length if the magnetisations are made more intense.

Cobalt decreases its length for low magnetisations and then increases for further intense fields.

Nickel on the other hand always contracts whatever the magnetic field strength.

The extent of these length alterations is very small and some idea can be given by stating that a rod one yard long of nickel will contract about two thousandths of an inch under a constant and intense magnetic field.

In 1928, G.W. Pierce of America utilised this phenomenon by applying instead of a constant field, an alternating current field of such a frequency as to strike the natural longitudinal period of the magnetostriction element or rod.

The rods expanded and contracted by magnetostriction and built up movements far in excess of those produced by constant direct current fields.

This principle of magnetostriction applied to mechanical longitudinal vibrations was patented by G.W. Pierce, with a view to their application to the transmission of compressed waves through sea water and to their reception as an echo on the same vibrator.

Owing to the high frequencies obtainable by longitudinal vibrations of the order of thousands of cycles per second according to the lengths of specimens used, this phenomenon comes under the category of supersonic frequencies or wireless frequencies.

For these reasons supersonic echo sounders may work at frequencies between 60.000 cycles and 10.000 .cycles per second.

The frequency having been decided upon settles the dimensions of the longitudinal vibrator or magnetostriction specimen and also the wireless electrical circuit which ultimately energises the specimen. The frequency and wireless wavelength are determined.

Nickel of ordinary commercial purity appears to be the most suitable magnetostrictive material for the purpose.

The rate of change of length with magnetization is very large for small values of H. The maximum peak value of alternating sinusoidal stress which can be usefully obtained from nickel with an upper limit of field strength of 50 gauss is of the order of 400 lb. per sq. in. It is of interest to note that the corresponding stress produced piezo-electrically in quartz by an applied potential of 2,000 volts per cm. is of the order of 4 lb. per sq. in.

I. *Cylindrical Oscillators, Scroll Type ; Longitudinal vibration.*

An example of this type of oscillator, containing about 0.5 kg of nickel, is illustrated in fig. 74. It is constructed by winding tightly on a mandrel long strips of nickel sheet and thin paper coated with cement. The hollow cylinder thus formed is consolidated by baking at an appropriate temperature. A load attached to one end serves to tune the oscillator to the desired frequency and to increase the area of vibrating surface in contact with the water. Such an oscillator is found to be sufficiently resonant mechanically and exhibits good magnetostrictive properties at supersonic frequencies. The only winding necessary consists of about 10 turns of low-resistance wire wound toroidally through the nickel cylinder as shown. Current through this winding produces circumferential magnetisation which results in simultaneous changes in the length, diameter and thickness of the nickel cylinder; the volume remains sensibly constant. Since it is desired to excite longitudinal resonant vibration, the appropriate frequency of alternating current must be supplied. A converse process, involving the Villari effect, takes place when the oscillator is used as a receiver.

II. *Ring Oscillators; Radial Vibration.*

This form of magnetostriction vibrator is a cylindrical pile of annular nickel rings (say 0.002 to 0.005 in. thick). These may be consolidated to form a solid resonant block by coating with a suitable insulating cement and baking under pressure. Alternatively, the laminations may be built up loosely into a pile so that they are free to vibrate individually and more or less independently. It is important, however, in the latter form of construc-

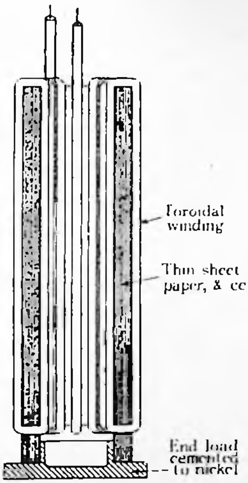


FIG. 74. — *Cylindrical Scroll-type Oscillator.*

tion to obtain a reasonable uniformity between the individual laminations. This is achieved by stamping the annular rings from thin nickel sheet and "shuffling" a large number of such stampings to obtain an average in each oscillator and to avoid progressive errors in diameter due to the wear of the stamping tools. The fundamental frequency f of radial vibration of a circular annulus, of width small compared with the diameter, is given by :

$$f = \frac{v}{\pi d}$$

where v is the velocity of sound in the material and d is the mean diameter of the annulus. For example, a ring of mean diameter 10 cm. resonates in this mode at a frequency f = 15.900 cycles per sec. A series of equidistant holes spaced round the periphery of the stampings accomodates the toroidal winding.

This arrangement leaves the sound-emitting surface, i.e. the edge of the stamping free from obstruction. The circular magnetization produced by current in the toroidal winding results in a small change in the diameter of the magnetized ring, the amplitude of this reaching its maximum value when the frequency of the magnetizing current coincides with f, the fundamental radial frequency of the annulus.

An example of this form of vibrator is shown in figure 75. It contains about 3 kg. of nickel stampings each 0.002 in. thick. The outer cylindrical surface constitutes the active sound-emitting surface in contact with the water. To prevent sound emission in opposite phase from the inner cylindrical face, the latter is covered with a layer of rubber mousse (1) or an equivalent air-filled space. The radiation damping of this form of oscillator may be controlled by varying the ratio of the surface area exposed to the water and the mass of nickel.

(1) Rubber mousse or expanded rubber froth is composed of small, watertight air cells.

The mean diameter of the annulus is determined by the frequency required, while the radiation damping is controlled by the width of the ring. If a very large amount of damping is required with a given amount of nickel the cylindrical pile of stampings becomes relatively long and narrow, whereas for relatively small radiation damping the pile should be short and wide. The proportions shown in fig. 75 have given good results in practice.

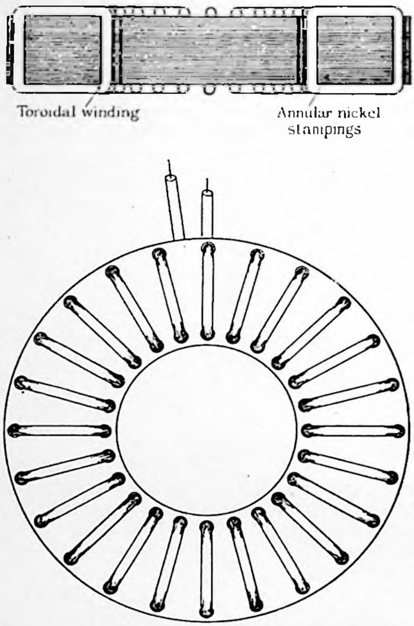


Fig. 75. — *Ring-type Oscillator.*

III. *Strip Oscillators; Longitudinal Vibration.*

A third form of oscillator is shown in Fig. 76. The thin nickel stampings are rectangular in shape and consist essentially of two nickel strips connected by two tuning legs. The longitudinal members which connect the tuning legs may, with sufficient accuracy, be

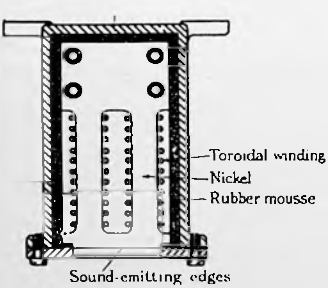


Fig. 76. — *Section through Strip Oscillator.*

regarded as loads and the legs as springs. By varying the length and width of the legs and the depth of the end loads, any desired frequency can be obtained. These rectangular nickel stampings are annealed, oxidized, or coated, in a similar manner to the circular stampings. They are insulated from each other and are mounted to form a rectangular block of the required size. The magnetizing coils are wound around the tuning legs which form part of the closed magnetic circuit. As in (II) the edges of the stampings constitute the active sound-emitting surface in contact with the water, the opposite vibrating edges being screened as before by means of an air cavity, e.g. a layer of rubber mousse. The rectangular block of stampings is mounted in a suitable casing, not necessarily watertight, which may be lined with rubber mousse.

It should be observed that in most of these forms of magnetostriction oscillator it is possible to permit free access of water to the surfaces of the nickel and the associated windings.

Air Reflectors - Angle of Sound-beam.

In order to obtain sufficient "directionality" in the magnetostriction transmitter and receiver, the oscillators just described, more particularly types (I) and (II) must be mounted

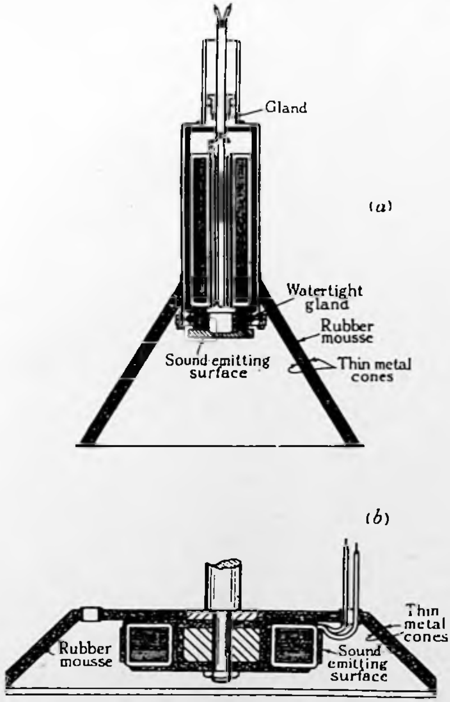


FIG. 77 (a & b). — *Scroll and Ring Oscillators mounted in conical reflectors.*

in some form of reflector (fig. 77 a & b). The semi-angle of the primary conical beam of sound emitted from a circular source of diameter D is given by.

$$\Theta = \text{arc sin } (1.22\,\lambda / D)$$

where λ is the wavelength of sound in the medium under consideration. Consequently at

a particular frequency, e.g. 15 kilocycles per sec. (λ = 10 cm. in water), the angle of the primary beam of sound is fixed by the effective diameter of the source; analogous considerations apply also to the directional properties of the receiver. The sound energy from a source of diameter large compared with a wavelength of the sound emitted is confined to a relatively narrow cone. This is an advantage from the point of view of economy of sound energy; but in its practical application to echo sounding a very sharply directional transmitter and receiver may result in a loss of some of the echoes, particularly in a moving ship and oved a rapidly shelving or undulating sea-bed. The choice of the angle of the beam is therefore a compromise.

With the cylindrical and ring type oscillators described above, an increase in effective diameter is obtained by means of a reflector, since the dimensions are too small to ensure sufficiently good inherent directional properties. Air is the best reflecting medium for use under water, a relatively thin layer producing total reflection. Two types of reflectors which have given good service are shown in Fig. 77. In both of these the reflector is formed by a pair of thin conical metal spinnings enclosing an air cavity. The double-walled enclosure is made watertight but to avoid failure of reflecting properties in case of leakage, the cavity is filled with rubber mousse, which may be regarder as equivalent to air alone. The theoretical directional curve for type (b) reflector is shown in Fig. 78.

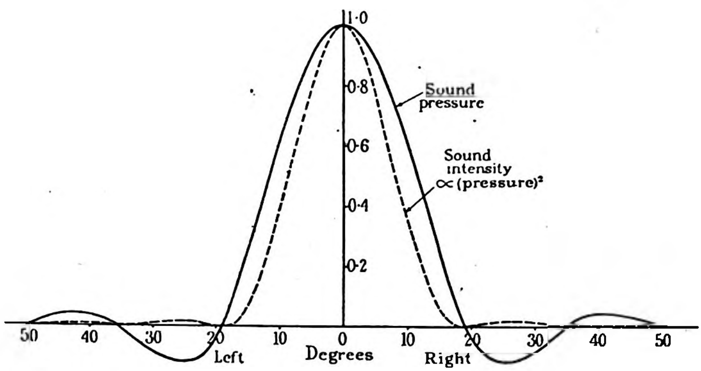


FIG. 78. — *Theoretical sound-distribution curve of ring type oscillator (15 kilocycles per sec.) with 12 in. dia. reflector.*

The semi-angle of the primary cone of sound is about 20° with an oscillator of frequency 15 kilocycles per sec. The beam angle of the smaller type (a) is somewhat greater on account of its smaller diameter.

In practice, although the transmitter can also be used as a receiver, it is preferable to have two separate identical instruments.

The sensitivity of the receiver depending on its initial magnetic state, it is therefore better to polarize it by submitting it to the action of a strong current.

In order to avoid the necessity for dry docking a vessel to install the echo sounding projectors the frequency of the supersonic transmission is so chosen that the ratio of thickness of hull plating (normally 3/4 inch) to the wavelength in the steel of the hull plating is as small as possible, in order to transmit directly through the plate the greatest percentage of energy impinging on the plate from inside the vessel.

Steel has a velocity of sound of 5,000 metres (16,400 ft) per second so that the wavelength in steel for the same frequency already discussed, namely 20,000 cycles/sec. is :

$$\frac{5.000}{20.000} \times 100 = 25 \text{ centimetres } (9.84 \text{ in.})$$

The ratio, steel thickness: wavelength, can therefore only be made small and the percentage of energy transmitted through the plate made high if the steel wavelength is large. Consequently the lower the frequency used the better the penetration of sound wave through the plate.

It should be realised that to operate an echo sounder through the hull plating requires considerably more power than would be required if the projector faces were directly operating on the sea water without the consequent loss in passing through the hull plating both in transmission and back again in reception.

Theoretically, the width to be traversed should be chosen equal to an exact multiple of a half wavelength.

Where projectors operate through a hole cut in the vessel's bottom, greater ranges of depth can be obtained or alternatively the same depths can be obtained with less power.

a) British Admiralty Silent Super-Sonic Echo Sounder.

(See also: *Hydrographic Review*, Vol. X, N° 2, Nov. 1933, p. 160; Vol. XI, N° 2, Nov. 1934, page 36; Vol. XIII, N° 2, Nov. 1936, pages 78, 85; Vol. XIV, N° 2, Nov. 1937, p. 211; Vol. XV, N° 2, Nov. 1938, p. 26).

The firm of Henry Hughes and Son Ltd have in regular production, since 1930, a new type of echo-sounder utilising super-sonic waves, the operation of which is silent.

The system of transmission comprises a transmitter operating by magnetostriction, producing a wide beam.

The transmitter (fig. 79), comprises a small cylindrical tank welded or clamped to the ship's plating and containing the magnetostriction element and a reflector. The tank is kept full of water, a small pipe from a feed tank making up any loss by leakage or evaporation.

The receiver is exactly similar to the transmitter and is attached to the hull like the transmitter but on the opposite side of the keelson. The transmitter and receiver tanks are cut to match the floor angle at the point chosen for their installation; they are then clamped down on rubber seating rings or electrically welded.

These apparatus are designed to operate at their natural frequency for radial resonance, which is approximately 16,000 vibrations per second, that is about two times less than the electro-piezo-quartz instruments, the working frequency of which is of the order of 30,000 to 40,000 per second. This lower frequency assures easier penetration through the particles of the liquid mass and enables depths exceeding 1,000 fathoms to be attained without difficulty. Undoubtedly for greater depths, for deep-sea sounding and in oceanographic work, the sonic system possesses greater penetrative power but the use of such devices implies special installations such as those, for instance on the British surveying vessel "Challenger", or on the research vessel "Mabahiss" of the John Murray expedition: the pneumatic or magnetic hammer transmitters specially adapted for the work, functioning on frequencies of about 1250 to 1500 cycles per second.

The emission is produced by deadened impulsion. The high frequency current for energising the transmitter is provided by discharging a large condenser through the windings and the circuit employed is shown in fig. 80. At a predetermined time the key K switches over to position 2, and immediately the oscillatory current and the vibrations of the transmitter build up to their maximum amplitude in a few oscillations and then decrease exponentially in amplitude.

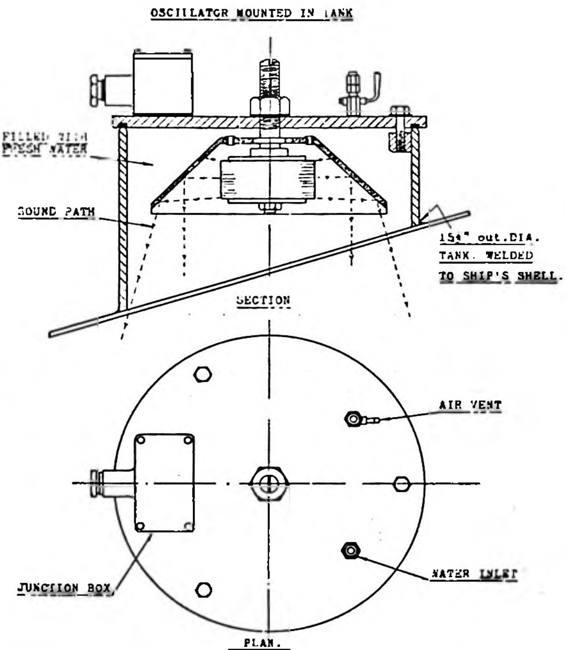


FIG. 79

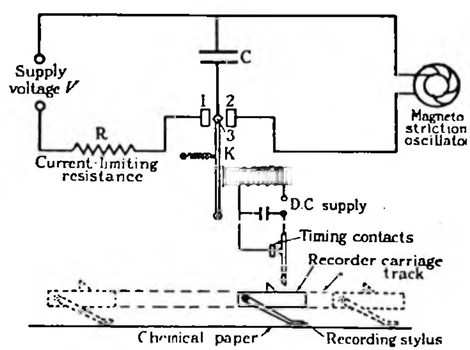


FIG. 80. — *Damped-impulse transmission.*

At the time of reception, the small electromotive forces developed in the windings of the magnetostriction receiver are amplified by means of a step-up transformer with tuned secondary winding. The output from this tuned circuit is applied to the grid of the first valve of an amplifier.

The commanding levers are contained in a noncorrosive aluminium metal box which

is fitted in a suitable position on the bridge. The instrument is made either with pointer dial indicator or with recorder.

In the type with indicator, (fig. 81), the case contains a constant speed motor and a disc carrying 3 rotary switches in step with a rectangular solenoid, the speed of which is proportional to the velocity of the transmitted sound waves, having regard to the particular scale for which the instrument is calibrated. A soft iron needle is mounted inside the solenoid so that its axis of rotation coincides with the axis of rotation of the solenoid. If the solenoid is energised by the impulsion received when the echo returns, the needle tends to set itself parallel to the magnetic axis of the solenoid. The pointer which moves over the dial is coupled by a shaft to this magnetic needle, and indicates the depth given by the echo against the graduations of the scale.

In the sounders with recorder, the recorder is of the electrolytic type already described, page 39.

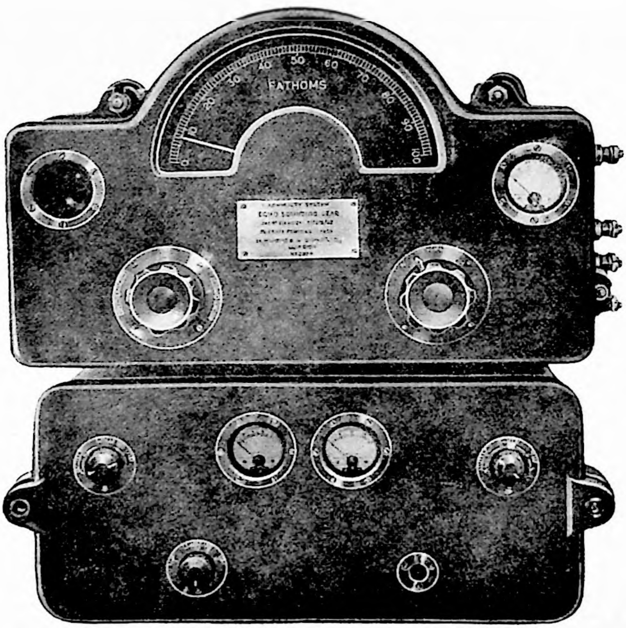


Fig. 81. — *The Husun Dial Indicator.*

In the recorder with the straight scale system (sounders models MS III and MS IV) (fig. 82 and 83), the stylus moves across the paper in a straight line; thus the record is only "compressed", it is not "distorted".

Figure 83 is a diagrammatic representation of the Recorder mechanism. The essential features are the motor A driving through a gear box B and shaft C, the switch cam D, and the helicoidal scroll E. The revolving of the scroll E drives the stylus F with a constant velocity throughout the width of the paper and lifts it off the paper on its return stroke. The paper is driven at a constant speed by gearing to the motor drive. The transmitting switch, which controls the moment of transmission, is operated by a cam coupled to the motor.

Phasing. — It is clear that if there is an interval between transmission and the instant the stylus passes the zero of the scale, then the recorded depth will not be true, but if

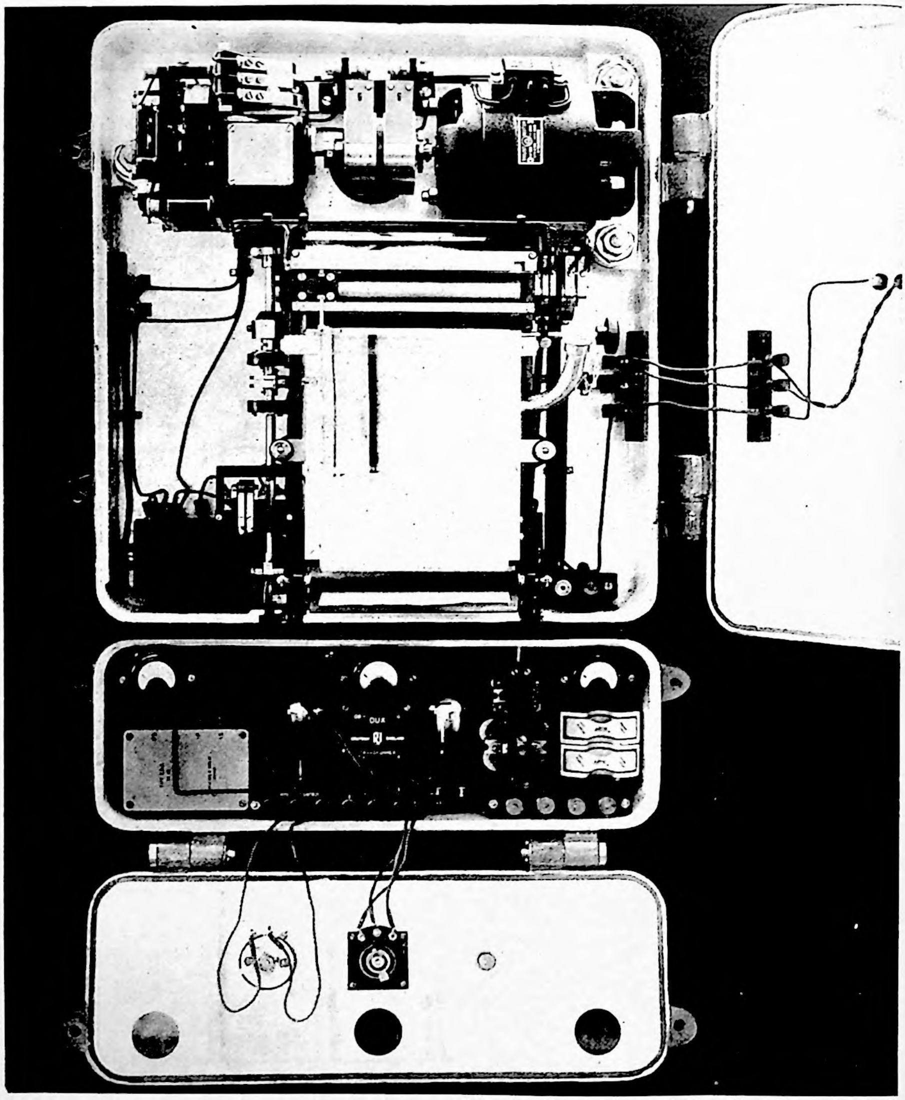


FIG. 82. — *Admiralty Super-Sonic Pattern with Magneto-Striction Transmission Types M.S. III & IV.*

the interval is known, then the echo depth corresponding to the interval can be added to the recorded depths, to give the true depth. Advantage is taken of this fact to increase the range of the recorder beyond the depth shown on the scale without the necessity of contracting the divisions of the scale. Referring again to (fig. 83), transmission is caused by the break of the contacts of S, and these are mounted on a dial L, which can be turned by hand about the cam D. Hence since the cam D is rotating at a definite known speed, the displacement of S, through a known angle, results in a definite interval between transmission and the instant the stylus passes the zero. This interval can be readily expressed in fathoms and can be engraved on the dial to show the amount to be added to the scale reading against the governing knob.

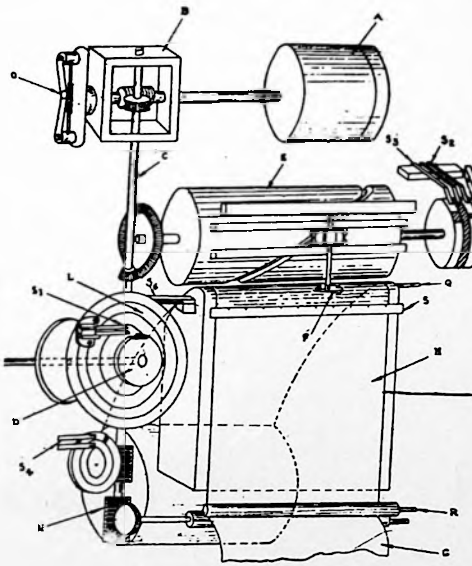


Fig. 83

A spring plunger engages in slots cut in the periphery of the dial to determine this definite angular displacement.

In this way the echo may be followed from phase to phase up to a depth of several times the nominal range of the machine.

It may be thought that the appearance of an echo at 30 fms on the scale at zero phase for depths of both 30 fms and 280 fms would lead to confusion. This is not the case, however, as the depth is generally known to sufficient accuracy to distinguish between the two cases. Further, the intensity of the echo at 30 fms is so much greater than that at 280 that very little experience is required to distinguish between the two cases.

In the curved scale recorder (fig. 84 & 85) the stylus describes an arc of circle which enables a simpler form of "drive" to be used, admitting of much higher pen-speeds and also allows the use of change gears, so that two or more scales can be given if required.

The main principle of operation is the same and the same system of recording is used, the only difference is that the form of the profile is based on a curved track instead of a straight track.

Using high speed of drive, a scale of 0 to 40 ft., can be given; this allows a space of 1/8 inch to one foot.

The same machine geared down to 6 to 1 would, on its slow speed, have a scale of 0 - 40 fathoms with 1/8 inch = one fathom.

In the type M.S. X (Rotating Arm Double Range Scale Recorder) particularly designed for accurate surveys an arm of 9-inch radius was used in order to give a high pen speed in traversing the paper, without running the instrument at an unduly large number of revolutions.

In order to have a recording scale on which the depth of one foot is represented by 1/8 th inch, a pen speed of 26 feet per second is necessary.

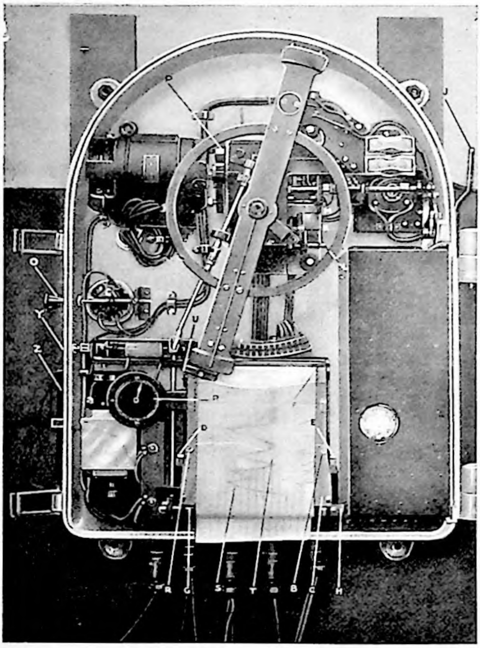
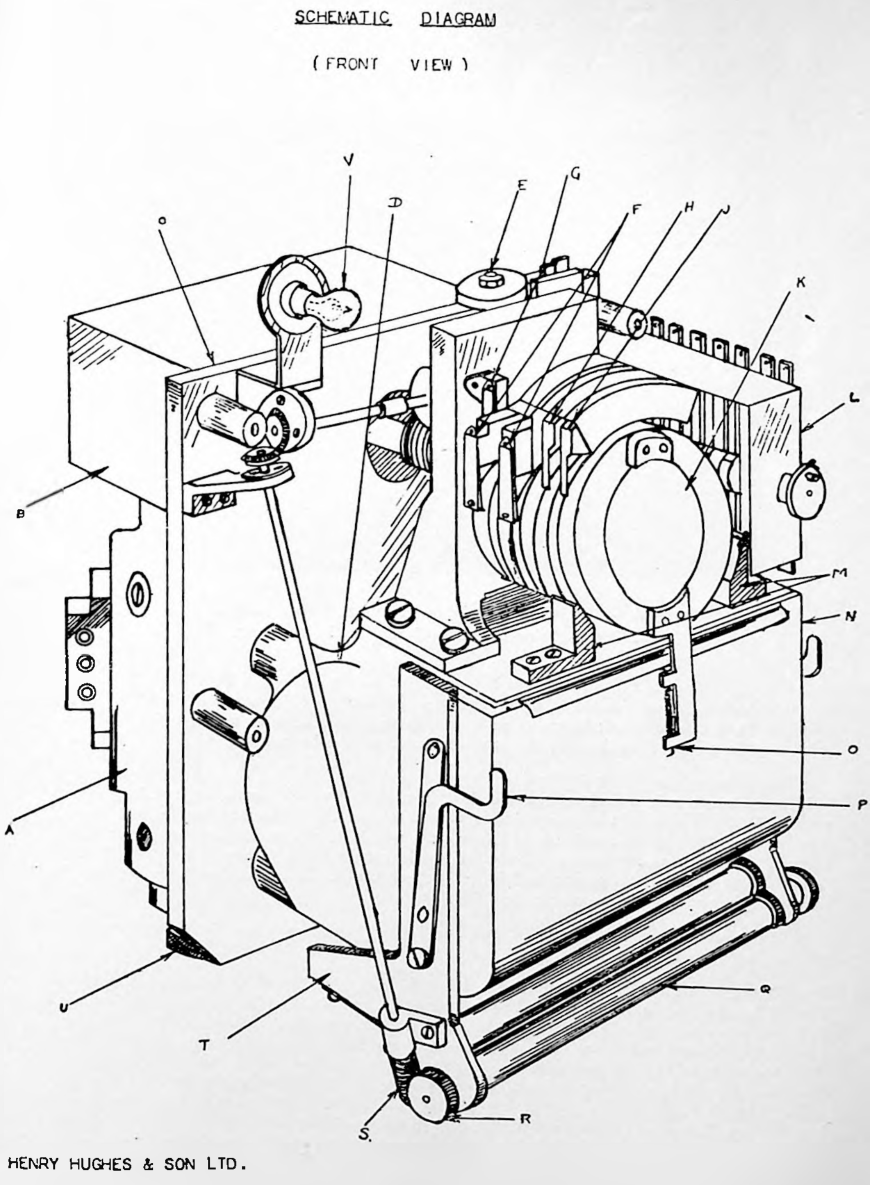


FIG. 84. — *Hughes Recorder, with rotating arm.*

This instrument may be used on surveying boats with the oscillators hung outboard: mounted in a streamline form, they offer very little additional resistance. Soundings may be taken by this method to an accuracy of 3 inches (1/10,000 sec.) up to a speed of 18 knots. (Fig. 86).

In the echo-sounder M.S. XII (Rotating Arm Curved Scale Recorder "Universal" Pattern), the radius of the rotating arm has been reduced so as to render the whole less cumbersome and more compact. In view of its wide application it has received the name of "Universal".

This little recorder is only 16 inches high, 11 inches wide and 11 inches deep: the radius of the rotating arm has been reduced to slightly under 4 inches. It has a two-speed gear with a 6: 1 ratio so that in open water it takes soundings in fathoms (0 to 130) and, when it has passed the 10-fathom line and enters pilotage waters, it can take soundings in feet (0 to 130).


SCHEMATIC DIAGRAM
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S.
HENRY HUGHES & SON LTD.

Fig. 85

The application of this machine is very wide. The makers can deliver it with different scales for the two speeds, usually of the ratio 4 : 1, 6 : 1, 10 : 1. For British surveys the 6 : 1 ratio is generally preferred, representing fathoms and feet; a simple lever changes from one to the other as necessary. The scale now adopted in hydrography is one giving 0 to 150 feet/fathoms, that is to say, representing one foot by 1/30 inch.

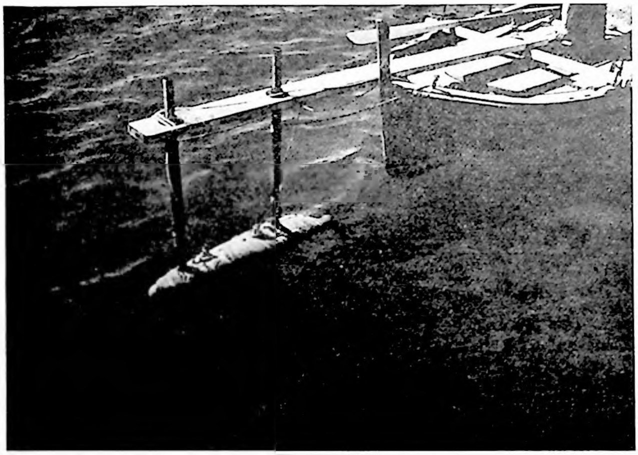

FIG. 86. — *Temporary rig for streamlined oscillator.*
British Admiralty Echo Sounder Boat Gear.

In addition, when desired, phasing switches admitting of increases in depth by steps of about 75 % can be fitted; hence, in an instrument having a scale of 0 to 150 feet/fathoms, with a 75 % phase, soundings up to 450 feet/fathoms can be assured.

The speed of the motor is regulated by two contacts, A & B (Fig. 87) which short the field resistance. A is a carbon disc mounted in a holder which can be adjusted by means of handle C. There is a clicking device which retains the handle at the desired setting. The contact "B" is mounted on a flat spring which is under compression with motor stopped, but with motor running the centrifugal force on the governor weights D tends to straighten out the flat spring and brings copper contact B to A, thus shorting out the resistance in series with the motor field.

The motor A (fig. 85) is coupled two-speed gear in the gear-box B which is mounted on the baseplate C.

The paper trough D is fixed on the front of baseplate C and mounted on top of the trough is a bracket in which is the bearing for the drum shaft. On the front of this shaft is the drum which is built up of insulated discs with brass rings on the outside. The front ring is continuous, and is for bringing the echo impulse to the stylus by means of brush J. The second ring has segments in for the depth marking lines and has a feed brush H. The next ring has a cam on it, and actuates the switch G, which is the initial suppression switch that is required for suppressing the interference caused by the transmission at the beginning of the scale. The ring at the back is in the form of a cam which operates the transmitter contact switch F. The transmitter operates once every revolution of the drum.

The recording paper is driven by the worm wheel R and the roller Q. The pen arm is fixed to the outer brass ring under brush J. The stylus is a wire bent down at the ends, one end passes over the paper, and the other passes over the ramps (or insulating

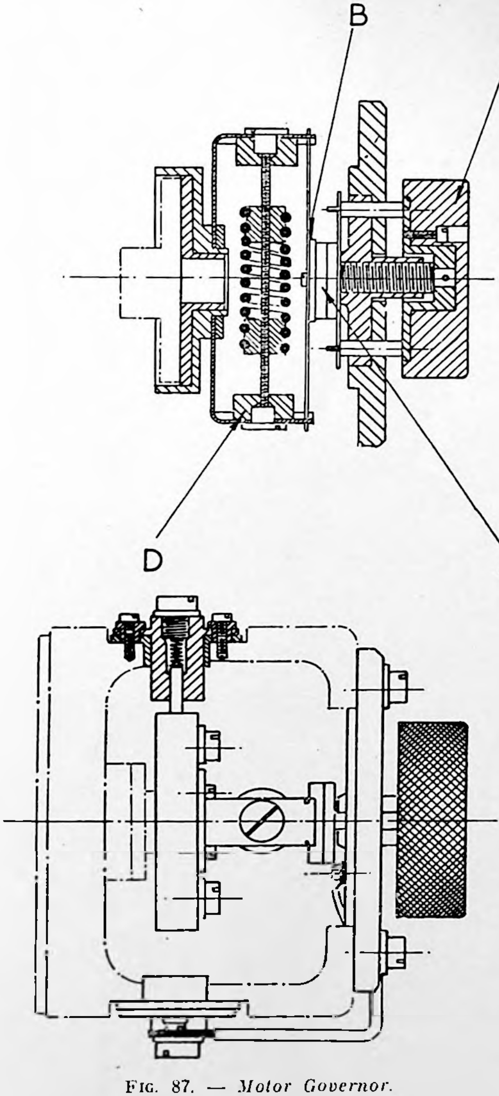

FIG. 87. — *Motor Governor.*

blocks). The ramps M are for lifting the stylus on and off the paper. The ramp on the left lifts the stylus while passing over the roller, and lowers it on the paper at the beginning of its traverse across the chart. The ramp on the right again raises the stylus while passing the roller at the top of the trough, and lowers it ready for its next revolution. Attached to this ramp is a rubber wiper which cleanses the stylus every revolution.

The heater for drying the chart is hinged, so that by bringing the heater close to the paper, drying can be made quicker.

With straight scale recorders, emissions are of the order of 60 per minute; with the rotating arm curved scale, soundings in shallow water may be carried out at the rate of 220 soundings per minute for high-speed and 60 soundings per minute for low-speed. On the first of these cadences, and steaming at three knots, a record of soundings at intervals of about 20 cm. on the bottom may be obtained, thus allowing a study of detail hitherto impossible to obtain by means of any of the old sounding methods by line or wire.

b) **Tho Marconi Magnetostriction Echo-Sounder.**

(See also: *Hydrographic Review*, Vol. XV, N° 2, Nov. 1938, p. 57 and 59).

The Marconi Company manufactures an echo-sounder for navigation 0 to 150 fathoms based on the same principles.

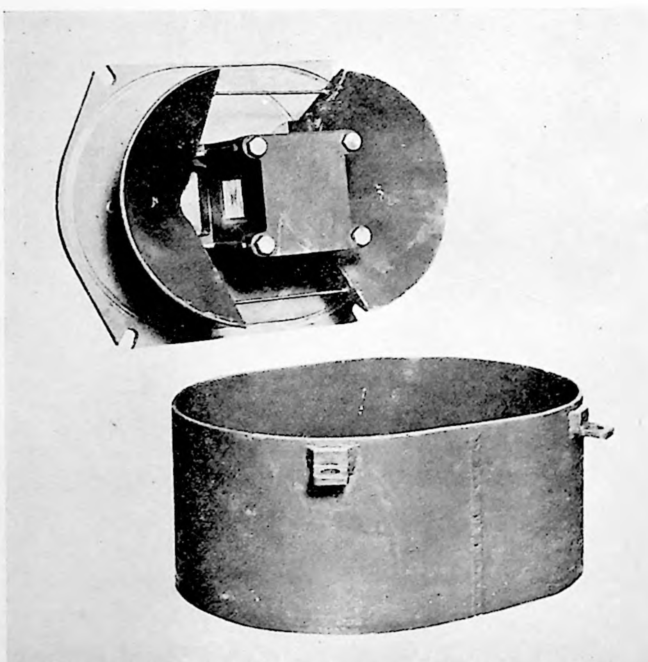

FIG. 88. —*Marconi navigational equipment 0 to 150 fathoms. Projector Element on top plate with reflectors and tank below.*

Fig. 88, represents a Projector element on top plate with reflectors and tank below; Fig. 89, represents the high tension generator with charge and discharge transmitting relay; the reception takes place on an electrolytic recorder of the type already described.

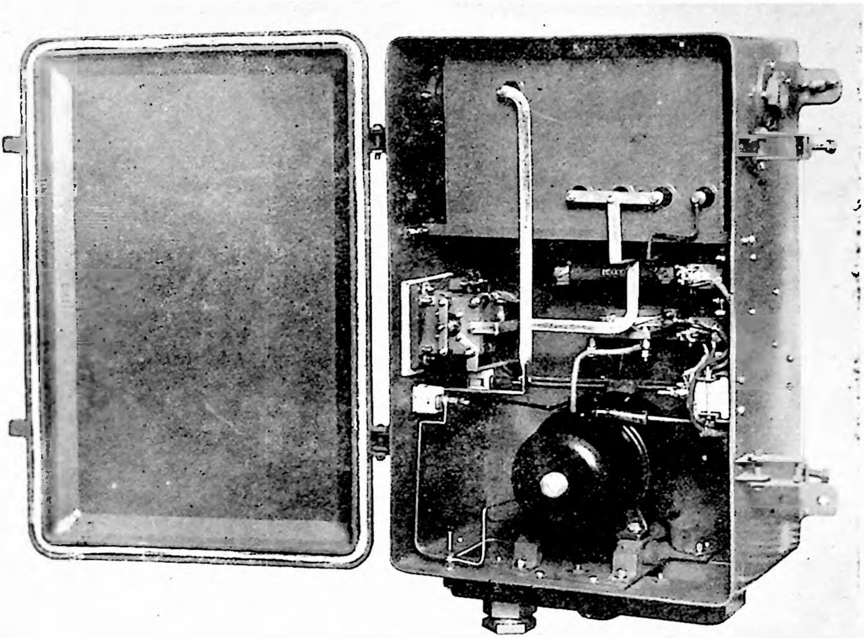

FIG. 89. — *Marconi Navigational Equipment 0 to 150 fathoms. Transmitter unit. Showing high tension Generator. Condenser bank and charge and discharge transmitting relay.*

For deep sea soundings down to 3.000 fathoms. Marconi have manufactured a powerful type with a voltage of 2.000 instead of 1.500 and with a much larger condenser bank, which is placed in direct contact with the sea. The electrolytic recorder comprises 5 ranges:

0 - 150	fathoms.	purely for navigational purposes on the Cable Ship or survey vessel.
0 - 750	—	Deep sea ranges.
750 - 1500	—	
1500 - 2250	—	
2250 - 3000	—	

According to the instruments used, the number of soundings per minute is 7,6 or 16,4.

c) High Frequency Atlas Echolot of Atlas Werke, Bremen.

(See also: *Hydrographic Review*, Vol. XV, N° 2, Nov. 1938, page 65).

This echo-sounder is also based on the principle of magnetostriction: it comprises two nickel oscillators (a transmitter and a receiver) placed in the bottom of the ship.

Fig. 90 gives a sketch of this sounder.

The inner scale (fig. 91) is graduated from 0 to 100 metres and the outer scale from 0 to 1.000 metres.

The depth indications succeed each other at an extremely rapid rate; on the 100 metres scale there are 7.5 soundings per second. The observer cannot separate out the individual depth indications; he sees only a permanent line which follows the slightest variations in depth somewhat like an indicating pointer. On the outer scale the depth indications succeed each other at a proportionately slower pace.

Owing to the large periphery of the scale, the readings may be effected at a distance from the apparatus, so that the observer is not under the necessity of approaching the apparatus closely each time a reading is desired.

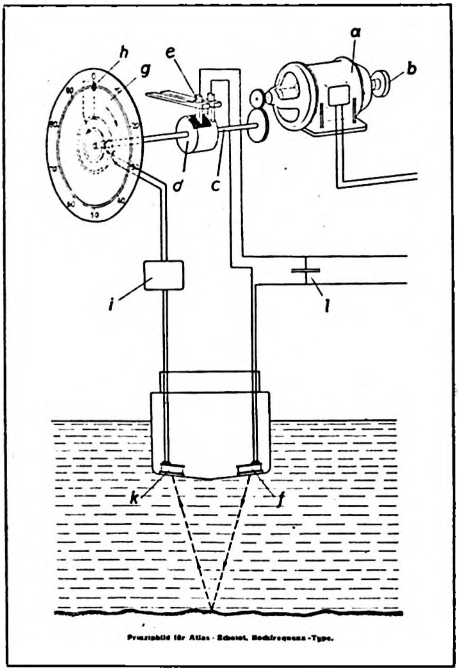

FIG. 90. — *High Frequency Atlas Echolot.*

The principle of the Echolot is explained with the aid of Figure 90. The straight neon tube (h) is inserted radially in the disk which is turned by the motor (a) at a constant speed behind the fixed scale (g) showing metres and fathoms. The centrifugal governor (b) either cuts in or out the series resistance of the induction circuit, thus assuring an exact number of turns with the necessary regularity, independent of the voltage fluctuation in the supply mains. On the gear axis (c) is also inserted a sliding contact (d) which, each time the neon tube passes the zero on the scale, discharges a condenser (l) into the windings of the magnetostriction oscillator (f), from which is sent out an impulse of short duration into the water. This short wave impulse reaches the ocean bottom, is reflected and arrives at the vessel where it impinges upon the magnetostriction tuned oscillator (k). This, acting as a receiver, transforms the sound waves into electrical oscillations. The latter are amplified by an amplifier (i) such that the neon tube (h) is instantaneously illuminated by a flash. The disk carrying the neon tube has turned through a predetermined angle during the time which has elapsed while the sound wave covered the distance from the ship to the bottom and back. The scale of depths is calibrated in metres and fathoms in accordance with the velocity of sound waves in sea water and therefore the depth of water in that locality may be read off directly on the scale at the place where the red line appears.

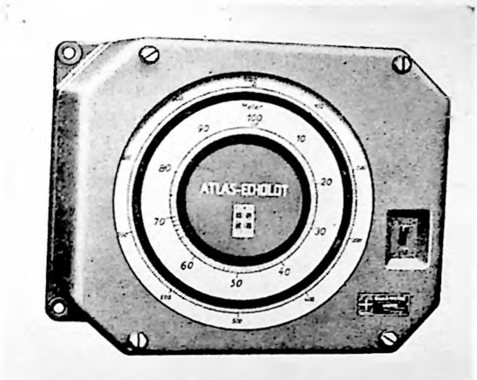

Fig. 91

For the range of 0 to 100 metres, the indicating disk makes 7.5 revolutions per second: equal to the number of soundings effected. For the outer scale, which has a range up to 1,000 metres, a second neon tube is attached to a concentric disk.

By means of the interrupter attached to the indicating apparatus, one may switch as desired from the outer to the inner scale.

Further there is a small regulating dial by means of which one can vary the amplification so that good reception is obtained at all depths. A second regulating dial is for the purpose of varying the grid voltage of the last tube, and consequently the sensitivity of the indication. The voltage necessary for the operation of the amplifier is taken from the ship's mains.

For the graphic recording of the depths, one may attach the Atlas Echograph to the indicating apparatus and obtain thus an indication of the depth in two ways, i.e. by the optical method and the graphic method.

XIII. General remarks on Echo-Sounding methods.

The accuracy of depths obtained by acoustic soundings was examined during the cruise of the German exploring ship "Meteor" in the Atlantic Ocean, 1925-27. Special reversing thermometers were used to measure the temperature of sea water at various depths. Each thermometer is protected by a solid glass tube, blow-lamp soldered, in order to avoid the influence of pressure which would alter the indications of the instrument and might even cause its breakage. This method of thermometric measurement of depths consists in the simultaneous use of a thermometer protected against pressure and an unprotected thermometer. The pressure, and consequently the common immersion depth of both instruments, is deduced from the difference in the temperatures indicated by the two thermometers. It has been possible to manufacture these thermometers with a sufficient degree of solidity to resist breakage down to a depth of 6,000 m., whilst observing the condition that the raising of the level of mercury must remain proportional to the pressure. By this indirect method of control, applied to wire and sonic soundings effected simultaneously in 51 stations, it has been thought possible to prove that on an average, wire soundings, after correction, give a value in excess by about 0,4 per cent, and sonic soundings a value of about minus 0,3 per cent.

The accuracy of sonic soundings is therefore superior to that of all hydrostatic soundings utilised up to now in navigation, and even to that of the deep sounding with a steel wire utilised in oceanography.

In shallow water of 5 feet to 120 feet (1 m. 52 to 36 m. 60), the indications furnished by sonic soundings are more accurate than those obtained by ordinary soundings effected by experienced sounders. During the ship's course, the hand sounding line generally gives indications in excess of about 1 foot (30 cm.). With echo sounding, however, the intersection of sounding lines on the plotting sheet show depths correct to a few inches.

The closeness of the soundings and their graphic inscription leaves no particularity of the surveyed sub-marine profile undetected, and includes the location of wrecks, etc.

Echo soundings can be effected regardless of the speed of the ship. They permit immediate contact with the continental shelf and facilitate landing especially in foggy weather.

The average roll of a ship of about 10° has no influence on ultra-sonic sounding; if the roll, however, is of about 20°, certain echoes may remain undetected, but the soundings are always correct when transmissions are effected in the vicinity of the vertical position.

Magneto-striction transmitters fitted with a conic reflector of which the apex half-angle is between 20 and 30°, also have the directional property, and the comparatively short waves which they emit (about 4 inches, i.e. about 10 centimetres), have practically the same properties as ultra-sounds.

Echo-soundings are, of course, influenced by the form of the sub-marine relief : the *Meteor*, during its atlantic cruise in 1925-27, found in 310 control stations, echo soundings smaller by 1,6 % than wire soundings.

In certain cases, it is quite impossible to determine the corrections to be made to acoustic depths in order to obtain true depths. Thus, the depth of the water at the bottom (thalweg) of certain very deep sub-marine ravines can never be determined by acoustic methods, as the echoes on the ridge of the ravine which arrive first, cover the echoes coming from the bottom of the ravine (fig. 92) supposing, of course, that the latter are sufficiently powerful to be detected.

The intensity of the echo varies, for the same wave length, inversely to the square of the depth. As the instruments which utilise sounds of audible frequency can produce a

far more powerful emission than that produced by quartz ultra-sonic projectors, there is a double advantage in employing the former for measuring great depths.

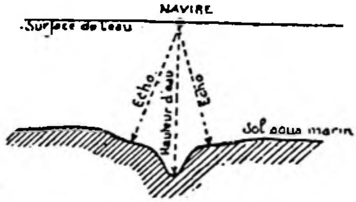

FIG. 92

Furthermore, owing to the high frequency of their waves, ultra-sounds partly escape, when received, the influence of parasitic noises such as those coming from the ship and those coming from the sea. The elimination, or at least the attenuation of these noises when the echoes are received has constituted the chief difficulty in the application of the new methods. Up to recently, quartz apparatuses seemed to be the best suited to determining small depths. The close resonance of the ultra-sonic sounder on high frequency transmissions is quite different to the scale of low frequencies and of perturbing noises, and therefore renders it indifferent to the various sounds and vibrations of the ship and of the sea.

It may be that this point of view will be modified following the appearance of magneto-striction sounders and the recent improvements made in sounders by means of blows.

In the apparatuses fitted with ear-phones, it is easy by practice to distinguish the returning echo from the "water noises" due to acoustic perturbations. In order to avoid the perturbations, it had been suggested to vary the immersion of the projector-receiver by the use of an instrument similar to an inverted periscope, in order that the power emitted by the apparatus be projected beyond the layer of water touching the hull which can be considered, owing to its position, as being very perturbed by the ship's course. However, it was soon discovered that such a device would, on the contrary, react unfavourably on the sounder when the speed of the ship is approximately 20 knots and when the violent movements of water on the surface of the apparatus engender parasites which mar the reception of the echo. It was therefore decided to instal the emitting side of the projector in the plane of the hull, at a suitable spot generally near the centre of the ship.

It is further possible to protect the receiving microphone from the influence of parasitic noises by placing it in a receptacle of which the width of the sides will be related to the length of the wave received.

The working of the sounders is greatly impaired when air bubbles exist on the track of the direct or reflected beam. The presence of a mixture of air and water under the keel, in the vicinity of the transmitter or of the receiver considerably reduces the intensity of the echoes. Each bubble of gas acts as a spring which absorbs the variations of pressure when the sound waves pass. The effect produced is in every way comparable to that of a cloud of smoke in the air with regard to the propagation of light. The place where the apparatus is mounted on the ship must therefore be selected with care, according to each type of vessel, in order especially to avoid the influence of the scum which gathers at the stern-post and which, in case of bad weather, may, owing to the ship's roll, run off under the keel.

To resume: in spite of a few handicaps, sonic soundings are more and more used for the requirements of hydrography, navigation and oceanography. Even fishing vessels utilise the new sounders which are easy to handle and which in addition, sometimes permit the detection of shoals of fished settled at different depths. Experience has proved, that these shoals produce a reflection of sound which is recorded by echo peaks on the recording graph.

The influence of currents so important and so little known in connection with wire soundings, does not seem to exist for echo sounding.

Echo sounding methods have the advantage of being rapid. Heretofore, the measurement of a depth of water of several thousands of metres required at least one hour's time, but now it is achieved in a few seconds only. This interval of time will reach a maximum. of 13 to 14 seconds when exploring the greatest sub-marine deeps known, where the height of the water, as is known, reaches approximately 10,000 metres. In this way, the new methods contribute greatly to the growth of our still somewhat imperfect knowledge of the topography of the bottom of the oceans, which cover more than two thirds of the globe. It did not appear at first that with these methods, an indication of the superficial

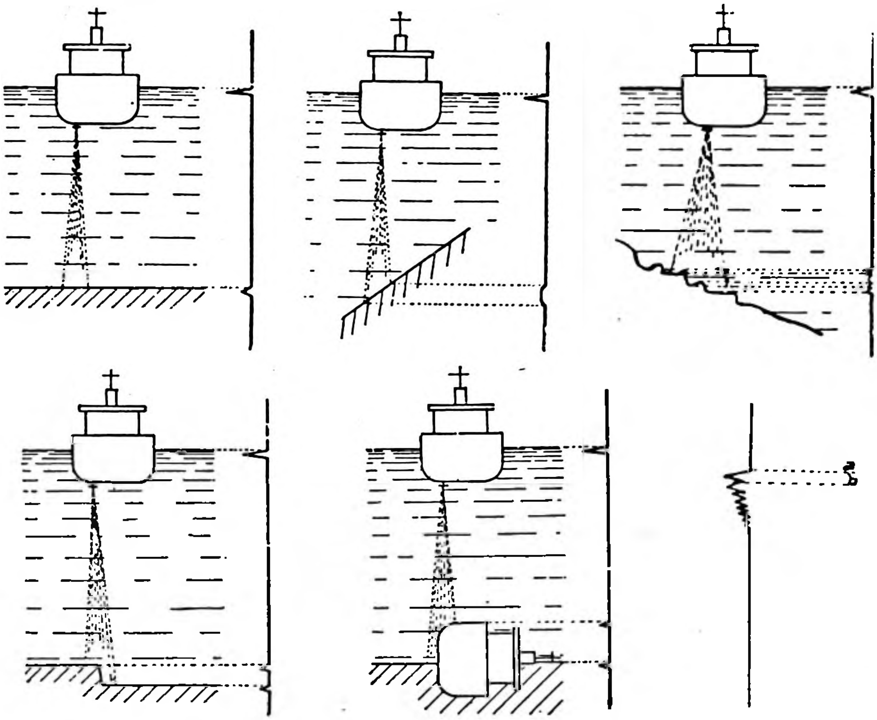

FIG. 93

structure of the sub-marine soil could be obtained. In reality, a close examination of the recording graphs has shown that, at least in depths where the nature of the bottom is of interest to navigation, it is often possible to ascertain by the form of the echo peaks whether the ground is constituted by hard sand or rocks, or whether it is covered by ooze or sea-weeds, the two latter sending back weaker echoes. Great progress has been achieved in this branch in the last two years. During experiments effected by the *Meteor* in the Baltic Sea in 1935, with quartz sounders of which the ultra-sonic beam "feels" so to speak the bottom of the sea, it was possible to obtain two echoes in each spot : a very feeble one on the upper layer of the soft ooze, and another one on a lower, harder layer corresponding probably to the foundation on which rested the ooze. When the ship passes over a rocky bank, the higher echo disappears and the profile furnished by the lower one joins that furnished by the apex of the bank.

A perusal of the records obtained with a Hughes apparatus of the British Admiralty during a survey of Lake Windermere in 1938, carried out under the auspices of the Freshwater Biological Association, revealed that on the bed of the lake there was a deposit of mud or silt, and that this deposit was arranged in strata of varying density. The mud deposit showed in the records very clearly because it consists of relatively soft material overlying the hard rock basin, or in some cases boulder clay, which formed the original lake floor. These results open up to scientists a new field of interest, enabling them to read from these strata the geological history of the district since the Ice Age.

The very accurate oscillograph analyses the form of the ultra-sonic reflected waves which can be modified by the undulations of the surface (fig. 93), as follows :

If the bottom is flat and horizontal, the form and duration of the reflected waves are similar to those of the original waves; the echo peak is then identical, with regard to form and breadth of base, to the transmission peak.

If the bottom is flat but very inclined on the horizontal axis : the progressive reflection of the various levels of the bottom lenghthens both the reflected waves and the echo peak.

If unevenness exists on the surface "felt", the echo peak is irregular and shows successive indentations corresponding to the principal successive levels of the bottom touched by the sound waves. This occurs when a ship passes over a rocky surface, a sub-marine cliff or a wreck. Similar results have frequently been obtained with magneto-striction sounders.

In shallow water or with a sufficiently strong transmission power, it has been possible to record double or multiple echoes due to the successive reflections of sound from the bottom and the surface of the sea.

Echo-sounding, therefore, is far from having reached its full development. A new process has been invented and is now comprised in the technical instruments of the hydrographer and of the mariner. Echo-sounders still have to be perfected and applied to the complete study of ocean depths; the completion of this study has become vital as a consequence of the hitherto unsuspected complexity of the relief of the regions of the globe covered by water, which was revealed by soundings effected during recent oceanographic cruises.

XIV

BIBLIOGRAPHY

We have grouped in this chapter the various books and articles published in recent years on Echo-Sounding. For the sake of reference, we have also mentioned some classical and historical works concerning sonic transmissions through water and the velocity of sound in sea water. The articles which refer more specially to the latter subject are marked with an asterisk.

BIBLIOGRAPHIE

Nous avons relevé dans ce chapitre les divers ouvrages ou articles ayant paru au cours de ces dernières années sur le sondage par le son. Nous y avons également mentionné, à titre documentaire, quelques ouvrages d'ordre historique ou classique concernant les essais d'émissions sonores dans l'eau et la vitesse de propagation du son dans l'eau et dans le milieu marin. Les articles plus spéciaux à cette dernière catégorie sont marqués d'un astérisque.

* 1827. J.D. COLLADON & J.K.F. STURM. - *Ann. de Chimie et de Physique 36*, 1827, pp. 236-257.

1840 Ch. BONNYCASTLE. - *L'Institut, Journal des Académies*, etc., 8, Nr. 316, 1840. pp. 25-26.

* 1841. J.D. COLLADON. - C.R. 13, 1841, pp. 439-443.

* 1848. H. v. HELMHOLTZ. - *Fortschr. d. Phys.*, 1848, pp. 110-114.

1859. MAURY. - The Physical Geography of the Sea. (La Géographie physique de la Mer). London, 1859, p. 184, § 678.

* 1879. Lord RAYLEIGH. - Die Theorie des Schalles, deutsch übersetzt von Fr. Neesen. Braunschweig 1879. (Theory of Sound. - Théorie du Son). Vol. II, London, 1896.

* 1880. G. STOKES. - *Mathematical and Physical Papers.* Cambridge, 1880, page 100.

1880. CURIE P. & J. - Développement par pression de l'électricité polaire dans les cristaux hémièdres à faces inclinées. (Liberation of Electrical Charges by Pressure in Hemihedral Crystals with inclined faces). *Comptes Rendus. Ac. Sciences*, Paris, 1880, pages 91, 294.

1888. M. BANARÉ. - Les Collisions en Mer. Première partie: Routes de Navigation et Signaux Phoniques en temps de brume. (Collisions at Sea. First Part: Shipping Routes and Sound Signals in foggy Weather). Paris, Imprimerie Nationale, 1888.

1890. W. VOIGT. Allgemeine Theorie der piezo- und pyro-elektrischen Erscheinungen an Kristallen (General Theory of Piezo- and Pyro-Electric Phenomena in Crystals. - Théorie générale des Phénomènes piézo-électriques et pyro-électriques des Cristaux). Dieterich, Göttingen, 1890.

* 1890. R. THRELFALL & J.F. ADAIR. - On the Velocity of Transmission through Sea Water of Disturbances of Large Amplitude caused by Explosions. (Vitesse de Transmission dans l'Eau de Mer des Perturbations à grande Amplitude causées par des Explosions). *Proc. Royal Soc.*, London, Vol. 46, 1890, pp. 496-541.

1893. Lord KELVIN. - On the Piezo-Electric Property of Quartz. (La Propriété piézo-électrique du Quartz). *Philosophical Magazine*, 1893, pp. 36, 331.

* 1896. Lord RAYLEIGH. - Theory of Sound. (Théorie du Son). Vol. II, 1896.

* 1897. Adolph LINDENKOHL. - Das spezifische Gewicht des Meerwassers im nordöstl. Pacifischen Ozean im Zusammenhange mit Temperatur und Strömungszustanden. (The specific Weight of Sea Water in the northeastern Pacific Ocean in Relation to Temperature and Current Conditions. - Poids spécifique de l'Eau de Mer dans la Partie Nord-Est de l'Ocean Pacifique dans son Rapport avec la Température et le Régime des Courants). *Dr. A. Petermann's Geogr. Mitteilungen*, Heft XII.

* 1899. Adolph LINDENKOHL. - Physiographische Probleme, Salzgehalt und Temperatur des Pacifischen Ozeans betreffend. (Physiographic Problems concerning the Salinity and Temperature of the Pacific Ocean. - Problèmes physiographiques concernant la Salinité et la Température de l'Océan Pacifique). *Dr. A. Petermann's Mitteilungen aus Justus Perthes, Geogr. Anstalt,* herausgegeben von Prof. Dr. A. Supan, 45 Band, Gotha, Justus Perthes.

* 1901 Martin KNUDSEN. - Hydrographische Tabellen (Hydrographic Tables. - Tables Hydrographiques). in-8° 63 pages. Bianco Luno, Copenhagen, 1901.

* 1902. Atlantischer Ozean. Ein Atlas von 39 Karten, die physikalischen Verhältnisse und die Verkehrsstrassen darstellend. mit einer erläuternden Einleitung und als Beilage zum Segelhandbuch für den Atlantischen Ozean. (The Atlantic Ocean. An Atlas of 39 Charts, showing the physical Conditions and the Traffic Lanes, together with and explanatory Introduction, and as Supplement to the "Segelhandbuch für den Atlantischen Ozean". - L'Océan Atlantique. Atlas de 39 Cartes, représentant les Conditions physiques et les Zones de Trafic, accompagné d'une Introduction explicative, et formant Supplément au "Segelhandbuch für den Atlantischen Ozean"). 2, Aufl. Hrsg. von der Direktion Hamburg, L. Friederichsen & C°.

* 1904. H. SIEVEKING & Dr. A. BEHM. - Akustische Untersuchungen. (Acoustic Investigations. - Etudes acoustiques). *Annalen der Physik.* Vierte Folge, Bd. 15, 1904, pp. 793-814.

* 1904. E. DE MEULEMEESTER. - Etude sur la transmission des sons émis dans l'eau et application à un système de signal maritime sous-marin. (An Investigation on the Transmission of Sound emitted in Water, and application thereof to a System of submarine maritime Signals). *Bulletin de l'Ass. Tech. Mar. et Aér.,* Paris. Vol. 15. 1904.

1904. A. DU BOIS-REYMOND. - D.R.P. 176 110 aus dem Jahre, 1904.

1906. H. v. HELMHOLTZ. - Die Lehre von den Tonempfindungen. (The Science of Sound Perception. - La Science de la Perception des Sons). Braunschweig. 1906.

* 1906. A. BEHM. - Über Schallmessung und Akustotecknik. (On Sound Measurement and Acoustotechnique. - La Mesure des Sons et la Technique acoustique). *Verhandlungen der Deutschen Otologischen Gesellschaft,* 15. Versammlung in Wien, 1906.

1907. J.B. MILLET. - Further results of submarine signalling by means of sound. (Nouveaux Résultats dans la Signalisation sous-marine au Moyen du Son). 1907.

1907. F. PECK. - Unterwasserschallsignale, ihre historische Entwicklung, ihre Fortschritte und ihr gegenwärtiger Stand. (Submarine Sound Signals, their historical Development, Progress and present State. - Signaux sonores sous-marins. Leur Développement historique, Progrès et Etat actuel). *Annalen der Hydrographie und maritimen Meteorologie,* Berlin, 1907. page 9.

1907. BARKHAUSEN. - Das Problem der Schwingungserzeugung. (The Problem of Oscillation Production. - Le Problème de la Production des Oscillations). Leipzig. 1907, page 19.

* 1907. KRUMMEL. - Handbuch der Ozeanographie. B. 1, 1907, page 285.

* 1908. V.W. EKMAN. - Die Zusammendrückbarkeit des Meerswassers, nebst einigen Werten für Wasser und Quecksilber. (The Compressibility of Sea Water, together with a few Values for Water and Mercury. - La Compressibilité de l'Eau de Mer et quelques Valeurs pour l'Eau et le Mercure). *Publication de circonstance, N° 43,* du Conseil Permanent International pour l'Exploration de la Mer. Copenhague, 1908.
Traduction française dans le Fascicule C1 des *Résultats des Campagnes Scientifiques du Prince Albert Ier de Monaco.* Monaco, 1939. pp. 44-83.

1909. WINKELMANN. - Handbuch der Physik. II. Bd. Leipzig, 1909.

1909. F. PECK. - Der heutige Stand des Unterwasserschall-signalwesens. (The present State of submarine Sound Singalling. - Etat actuel de la Signalisation sonore sous-marine). *Annalen der Hydrographie und maritimen Meteorologie,* Berlin, März 1909, page 103.

1910. G. SCHOTT & F. SCHU. - Die Wärmeverteilung in den Tiefen des Stillen Ozeans. (The Heat Distribution in the Depths of the Pacific Ocean. - La Répartition de la Chaleur dans les Profondeurs de l'Océan Pacifique). *Annalen der Hydrographie*, Berlin, 1910, p. 2.

* 1910. V. BJERKNES & J.W. SANDSTRÖM. - Dynamic Meteorology & Hydrography. (Météorologie et Hydrographie dynamiques). Part I, *Publication N° 88*, published by the Carnegie Institution of Washington.

* 1910. V.W. EKMAN. - Tables for seawater under pressure. (Tables pour l'Eau de Mer sous Pression). Conseil Permanent International pour l'Exploration de la Mer. *Publication de Circonstance N° 49*, Copenhague, 1910.

1911. H.F.W. FAY. - History and development of submarine signalling. (Historique et Développement de la Signalisation sous-marine). 1911.

1912. A tuneable diaphragm for hydrophones. (Diaphragme accordable pour Hydrophones). cf. *Proceedings Royal Society*, London, 99A., pp. 163-171.

* 1912. V. BJERKNES. - Dynamische Meteorologie und Hydrographie. (Dynamic Meteorology and Hydrography. - Météorologie et Hydrographie dynamiques). I. Teil, Braunschweig.

* 1912. A.H. CLARK. - A study of the salinity of the surface water in the North Pacific Ocean and in the adjacent inclosed seas. (Etude de la Salinité de l'Eau de Surface de l'Océan Pacifique Nord et des Mers fermées avoisinantes). *Smithsonian Miscellaneous Collections*, Vol. 60, N 13, Dec. 4.

1912. LEWIS RICHARDSON. - *Brit. Pat. Spec. Reports*, 1912.

1913. R.A. FESSENDEN. - D.R.P. Nr. 289 427 aus dem Jahre 1913.

1913. L. DE MARCHI. - Teoria degli scandagli d'alto mare. (Theory of high-sea Sounding. - Théorie des Sondages de haute Mer). R. Comitato talassografico Italiano. *Memoria XXXI*. Venezia 1913.

1914. R.A. FESSENDEN. - Long-distance Submarine signalling by Dynamo-Electric Machinery. (Signalisation sous-marine à grande Distance au Moyen de Machines dynamo-électriques). Lawrence Scientific Association, June 1914, p. 15.

1914. Prof. R.A. FESSENDEN. - On obtaining the depths of the sea by the echo method. (Obtention de la Profondeur de la Mer par la Méthode de l'Echo). *Trans. Am. Inst. of Elect. Ing.*, Vol. 33, October 1914, pp. 1569-1581.

1914. Dr. Reginald A. FESSENDEN. - Brevet américain N° 1-217.585.

1914. Dr. Samuel SPITZ, Oakland (Calif.). - Brevet américain N° 1-409.794.

1914. LANGEVIN ET FLORISSON. - Brevet pour les procédés et les appareils de sondage et de localisation d'un obstacle sous-marin.

* 1914-15. W.S. BRUCE, A. KING, D.W. WILTON. - The temperatures, specific gravities and salinities of the Weddell Sea and the North and South Atlantic Ocean. (Les Températures, Poids spécifiques et Salinités de la Mer de Weddell, ainsi que de l'Océan Atlantique Nord et de l'Océan Atlantique Sud). *Transactions of the Royal Society of Edinburgh*, Vol. II, Part I, page 71.

1917. H.B. BIGELOW. - Exploration of the United States C. & G.S. Steamer *Bache* in the Western Atlantic, January-March 1914, under the direction of the U.S. Bureau of fisheries "Oceanography". (Exploration du Vapeur *Bache* du Coast and Geodetic Survey des Etats-Unis d'Amérique dans la Partie occidentale de l'Océan Atlantique, de Janvier à Mars 1914, sous la Direction du Bureau of Fisheries des Etats-Unis d'Amérique "Oceanography"). App. V to the *Report of the U.S. Commission of Fisheries for 1915. Bureau of Fisheries Document N° 833*.

1918. JOLY. - Scientific Signalling and Safety at Sea. (Signalisation scientifique et Sécurité en Mer). *Phil. Mag.*, July 1918, page 1.

1918. LANGEVIN. - Exposé à la Conférence Interalliée sur la recherche des sous-marins par la méthode des ondes ultra-sonores. (Statement at the Inter-Ally Conference on the Search for Submarines by the ultra-sonic Wave Method). (Octobre 1918).

1919. Ing. Hyd. MARTI. - Sur un procédé de sondage en mer, sur un bateau en marche, basé sur la propagation du son dans l'eau. (On a Method of Sounding on the high Seas, in a Ship under Way, based on the Propagation of Sound in Water). *Comptes Rendus de l'Académie des Sciences*, 2 Juin 1919, 168, page 1100, et *Bulletin de l'Institut Océanographique*, Monaco, 5 août 1919, N° 358.

1919. H. BRILLIÉ. - Etude des Ondes Acoustiques. La propagation des ondes vibratoires et l'écoute sous-marine. (A Study on acoustic Waves. The Propagation of vibratory Waves and submarine Listening-in). *Génie Civil*, 23 et 30 Août, 6 Septembre 1919, Vol. 75, pages 171, 194 et 218.

1919. Unterwasserschallsignale 1919. (Submarine Sound Signals. - Signaux sonores sous-marins). Signal-Gesellschaft in Kiel.

* 1920. Ing. Hydr. MARTI. - Note sur la vitesse de propagation du son dans l'eau de mer. (Note on the Velocity of Propagation of Sound through Sea Water). *Annales Hydrographiques*, 3e Série, Paris, 1919-1920, pp. 165-179.

1920. Dr. Harvey C. HAYES. - Detection of Submarines. (La Détection des Sous-Marins). *Proc. of Am. Phil. Soc.*, January 1920, pp. 1-48.

1920. J. KRAUSS. - Die Unterwasserschallsignale und ihre Bedeutung für die Navigation. (The submarine Sound Signals and their Importance for Navigation. - Les Signaux sonores sous-marins et leur Importance pour la Navigation). *Annalen der Hydrographie*. Berlin, 1920, page 19.

1920. Dr. Harvey C. HAYES. - U.S. Navy MV-type of Hydrophone as an aid and safeguard to navigation. (Hydrophone Type MV de la Marine des Etats-Unis d'Amérique comme Aide et Garantie pour la Navigation). *Proc. of Am. Phil. Soc.*, Vol. 59, April 1920, pp. 371-404.

1920. A. DU BOIS-REYMOND. - Die grössten bei akustischen Schwingungsvorgängen erreichbaren Amplituden. (The greatests Ranges attainable in acoustic oscillatory Phenomena. - Les Amplitudes maxima pouvant être atteintes dans les Phénomènes oscillatoires acoustiques). *Zeitschrift für technische Physik*, I. 1920, p. 165.

1921. P. LANGEVIN. - Sound transmitters for Under-Water Signalling. (Emetteurs sonores pour la Signalisation sous-marine). British Patent N° 145691. 1921.

1921. A. DU BOIS-REYMOND, W. HAHNEMANN & H. HECHT. - Elektromagnetische Unterwasserschallsender. (Electromagnetic submarine Sound Transmitters. - Emetteurs sonores électromagnétiques sous-marins). *Zeitschr. f. techn. Phys.*, N° 1, 1921.

1921. A. DU BOIS-REYMOND, W. HAHNEMANN & H. HECHT. - Entwicklung Wirkung und Leistung des elektromagnetisch erregten Unterwasserschallsenders nach dem Telephonprinzip. (Development, Mode of Action and Performance of the electrically energized submarine Sound Transmitter according to the Telephone Principle. - Développement, Mode d'Action et Rendement de l'Emetteur sonore sous-marin construit sur le Principe du Téléphone, excité électromagnétiquement). *Zeitschrift für Physik*, II, 1921, pp. 1-33.

1921. Ing. Hyd. MARTI. - Le sondage en mer par le son. (Echo Sounding at Sea). *La Nature*, 20-VIII-21, pp. 125-127.

1921. Dr. A. BEHM. - Das Echolot. (The Echolot. - L'Echolot). *Annalen der Hydrographie*. N° VIII, août 1921, page 241 etc. (cf. *Rivista Marittima*, Roma, mai 1922).

1921. W. BRENNECKE. - Ausblicke für die Verwendung des Behm Echolots. (The Outlook opened concerning the Use of the Behm Echo-Sounder. - Perspectives qui s'offrent pour l'Emploi de l'Echo-Sondeur Behm). *Annalen der Hydrographie, etc.*, Berlin, Vol. 49, fasc. XI, 1921, page 363. *Die Naturwissenschaften*, N° 9, 1923, page 149 et seq.

1921. P.H. GALLÉ. - Het Echolood. (The Echo-Sounder. - Le Sondeur par le Son). *De Zee*, N° 7, 1921.

1921. C.D. JULIUS. - Het Echolood. (The Echo-Sounder. - Le Sondeur par le Son). *De Zee*, N° 10, 1921.

1921. Dr. H.C. HAYES. - How hydrophone focusses sound. (Comment les Hydrophones captent les Sons). *Marine Review*. Sept. Oct. 1921.

1922. Dr. Franz AIGNER. - Unterwasserschalltechnik (Grundlagen Ziele und Grenzen). (The Technique of submarine Sound Waves. - La Technique des ondulations sonores sous-marines). Submarine Akustik in Theorie u. Praxis. (Submarine Acoustics in Theory and Practice. - Acoustique sous-marine en Théorie et Pratique). In-8vo. 322 pp., 134 fig., 169 notes. Published by Boysen & Maasch, Hamburg, 1922. *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, page 234. *Hydrographic Review,* Vol. VI, N° 2, Monaco November 1929, page 226.

1922. G.S.S. - Echo sounding. Test carried out by the U.S.S. *Stewart* 20-29th June 1922. (Sondages par écho. Epreuves faites par le U.S.S. *Stewart* 20-29 Juin 1922). *Hydrographic Review.* Vol. I, N° 1, Monaco, Mars 1923, p. 71.

1922. E. SCHREIBER. - Über einige Versuchsergebnisse mit dem Anschütz-Echolot. (On some experimental Results with the Anschütz-Echolot. - Quelques Résultats d'Expériences avec l'Echolot Anschütz). *Annalen der Hydrographie,* Berlin, Février 1922, pp. 46 et suiv.

1922. Dr. H. MAURER. - Das Echolot. (The Echo-Sounder. - Le Sondeur par le Son). *Marinerundschau,* 1922, Heft 7, page 348 etc.

1922. Ing. Hyd. MARTI. - Brevet d'invention XII. 3, N° 568.075. Oscillographe enregistreur continu à grande sensibilité et son application au sondage continu par le son. (Continuous recording Oscillograph of high Sensitiveness and its Application to continous Echo Sounding). 7 Septembre 1922.

1922. Dr. H.C. HAYES. - Depth Sonic Sounder. (Le Sondeur acoustique). *Marine Review,* New York, October 1922, pp. 411-414.

* 1922. La vitesse du son dans l'eau de mer. (The Velocity of Sound in Sea Water). *La Nature,* Paris, 14-X-22, page 117.

1922. Dr. A. BEHM. - Über die Weiterentwickelung des Behm-Lotes und das Prinzip des Kurzzeitmessers. (On the further Development of the Behm Echo-Sounder and the Principle of the Time Michrometer. - Sur le développement ultérieur du Sondeur Behm et le Principe du Microchronographe). *Annalen der Hydrographie,* Berlin, Nov. 1922, p. 289.

1923. W.H. HOBBES. - Sounding the depths of Ocean. (Le Sondage des Profondeurs des Océans). *Michigan Technic,* Vol. 36, N° 2, janv. 1923.

1923. U.S. NAVAL INSTITUTE. - *Proceedings.* Janvier 1923.

1923. U.S. HYD. OFFICE. - Graphic representation of soundings from Newport to Gibraltar. (Représentation graphique des Sondages effectués entre Newport et Gibraltar). *Pilot Charts:* North Atlantic Ocean, January 1923; Central Amer. Waters January 1923; Indian Ocean, February 1923; North Pacific Ocean, February 1923.

1923. U.S. HYD. OFFICE. - Graphic representation of soundings taken by U.S.S. *Stewart,* July 1922, Mediterranean Sea. (Représentation graphique des Sondages effectués par l'U.S.S. *Stewart* en Juillet 1922, Mer Méditerranée). 3 sheets, January 1923.
Graphic representation of soundings taken by U.S.S. *Hull, Maryland, Milwaukee* with Sonic depth finder. (Représentation graphique des Sondages effectués par les U.S.S. *Hull, Maryland* et *Milwaukee* au Moyen du Sondeur acoustique). *U.S. Pilot Chart of the North Pacific Ocean.* Washington.

* 1923. E.B. STEPHENSON. - Velocity of sound in sea water. (Vitesse du Son dans l'Eau de Mer). *Physical Review,* Vol. 21, Feb. 1923, pp. 182-185.

1923. U.S. HYD. OFFICE. - Sonic Depth Finder, type S.E. 1378. (Le Sondeur acoustique, Modèle S.E. 1378). *Report of Bureau of Engineering,* Washington, 17th April 1923. — Renseignements fournis par le "Bureau of Engineering" du Ministère de la Marine, sur le Sonic Depth Finder, type S.E. 1378, le 17 avril 1923. *Hydrographic Review,* Vol. I., N° 2, Monaco, May 1924, p. 43. *Revue Hydrographique,* Vol. I., N° 2, Monaco, Mai 1924, p. 43.

1923. U.S. HYDR. OFFICE. - Bathymetric Chart of California. (Carte Bathymétrique de la Californie). *Pilot Chart, N. Pacific Ocean,* June 1923. *Pilot Chart, South Pacific Ocean,* June-July-August 1923, and N° 5194 (HO).

1923. BRÉSIL. - Détermination de la profondeur océanique au moyen des ondes sonores. (Determination of the Ocean Depths by Means of Sound-Waves). *Revue Maritime Brésilienne*, Juillet 1923.

1923. Dr. Gerhard SCHOTT. - Tiefseelotungen mittelst Echolot. (Deep-Sea Soundings with the Echo-Sounder. - Sondages de haute Mer au Moyen du Sondeur acoustique). *Annalen der Hydrographie*. Berlin, Août 1923, pp. 192-195. (Campagne de sondage par le son des navires américains *Stewart, Hull* et *Corry*. - Echo-Sounding Expeditions of the U.S.S. *Stewart, Hull* and *Corry*.

1923. ADAM. - Une nouvelle télégraphie sans fil sous-marine. (A new submarine Wireless Telegraphy). *Radioélectricité*, 1er Septembre 1923. p. 352.

1923. Edgar de GEOFFROY. - L'utilisation de l'ultra-son et de l'infra-son. (The Use of the Ultra-Sounds and Infra-Sounds). *Le Correspondant*, Paris, 10 Septembre 1923.

1923. W. BRENNECKE. - Das Behmlot. (The Behm Sounder. - Le Sondeur Behm). *Die Naturwissenschaften*, 1923, Heft 9.

* 1923. A.B. WOOD et Captain Harold BROWNE. - Rapport N° 79 au XIIIe Congrès International de Navigation, Londres, 1923. (Compte rendu d'expériences sur la propagation du son effectuées en 1921-22 à l'Admiralty Department of Scientific Research). (Report on Experiments on the Propagation of Sound carried out in 1921-22 by the Admiralty Department of Scientific Research).

1923. W. BRENNECKE. - Divers articles dans *Kosmos*, 1922. *Die Umschau*, 1923, *Hansa*, 1923-1924.

1923. Kapt. I. SCHUBART, D.S. - Das neue Behm-Lot. (The new Behm Sounder. - Le nouveau Sondeur Behm). *Die Umschau*, 35, 1923. page 548.

1923. G. WÜST. - *Die Naturwissenschaften*, 1923. p. 287.

1923. A.B. WOOD & H.E. BROWNE. - A radio method of locating positions at sea; application to navigation and to hydrographical survey. (Nouvelle Méthode radio-électrique de Détermination de la Position en Mer et son Application à la Navigation et à l'Hydrographie). *Proc. Phys. Soc.*, London, Vol. 35, part 3. pp. 183-194, 15-IV.

1923. A. TROLLER. - Les signaux sous-marins par ondes ultra-sonores (Submarine Signals by Ultra-Sonic Waves). *La Nature*, 1923.

* 1923. A.B. WOOD, H.E. BROWNE and C. COCHRANE. - Determination of Velocity of Explosion Waves of Small Amplitude in Sea Water. Variation of Velocity with Temperature. (Détermination de la Vitesse des Ondes d'Explosion de petite Amplitude dans l'Eau de Mer. Variation de la Vitesse avec la Température). *Proceedings of the Royal Society*, A. Vol. 103. 1923. page 284.

1923. Harvey L. CURTIS & Robert C. DUNCAN. - A method for the accurate measurement of short-time intervals. (Méthode pour mesurer avec Précision de courts Intervalles de Temps). *Scientific Paper N° 470 of the Bureau of Standards*, Washington, 1923 in 8°. 38 pp., 11 fig. Price: 10 cents. (See also *Hydrographic Review*, Vol. VI. N° 1. Monaco, May 1929, p. 213. *Revue Hydrographique*, Vol. VI. N° 1. Monaco, Mai 1929. page 227).

1923. André BOURGEOIS. - Le repérage des roches sous-marines, etc. (Locating sub-surface Rocks, etc.). *La Science et la Vie*, Décembre 1923, p. 352.

1923. BUREAU HYDROGRAPHIQUE INTERNATIONAL. - *Publication Spéciale N° 1*, Le Sondage par le Son, Monaco, Décembre 1923. International Hydrographic Bureau. *Special Publication N° 1*, Echo-Sounding, Monaco, December 1923.

1924. N.H. HECK, E.A. ECKHARDT, M. KEISER. - Radio acoustic method of position finding in Hydrographic Surveys. (Méthode radio-acoustique pour déterminer le Point pendant les Levés hydrographiques). *Special Publication N° 107 - U.S.C. & G.S.* Price: 10 cents.

* 1924. N.H. HECK and Jerry H. SERVICE. - Velocity of Sound in Sea Water with tables. (Vitesse de Transmission du Son dans l'Eau de Mer, et Tables). *U.S. Coast and Geodetic Survey Special Publication N° 108*, Washington. Government Printing Office, 1924, and *Hydrographic Review*, Vol. III, N° 1, November 1925, pp. 69-100, and Vol. IV, N° 1, May 1927, p. 229. *Revue Hydrographique*, Vol. III. N° 1, Novembre 1925, pp. 67-98 et Vol. IV, N° 1, Mai 1927, p. 253.

1924. M. MARTI. - Le Sondage en Mer par le Son aux grandes profondeurs au moyen de détonations. (Deep sea sounding by means of detonations). 27 illustrations. Cf. *Annales Hydrographiques*, 1923-1924. Imprimerie Nationale, Paris, 1924, pp. 187-214.

1923. LANGEVIN-CHILOWSKY. - Repérage des obstacles sous-marins par les ondes ultra-sonores, système Langevin-Chilowsky. (Locating submarine Obstructions by means of ultra-sonic Waves, Langevin-Chilowsky System). *La Technique Moderne, Paris*, 1er Janvier 1924 pp. 23-24 et 28, *Bulletin de l'Association Technique Maritime et Aéronautique*, Paris 1924

1924. LANGEVIN. - Note sur les ultra-sons et l'utilisation de leur écho. (Note on ultra-audible Sounds and the Use of their Echöes). *Bulletin technique du Bureau Veritas*, Février 1924.

1924. A. BR. - Les ondes ultra-sonores. (Ultra Sonic Waves). Cf. *Rivista Marittima*, Rome, Février 1924, p. 485.

1924 EIN NEUES LOTUNGSVERFAHREN. - (Un Nouveau provédé de sondage). (A New Method of Sounding). Cf. *Marine Review*. November 1924. Cf. *Annalen der Hydrographie und Marit. Met.* Heft III., Berlin, 1925, p. 109.

1924. Dr. H.C. HAYES. — Measuring Ocean Depths by Acoustical methods (U.S.A.: angle of reflexion method, standing wave method, echo method. (La Mesure des Profondeurs marines par Méthodes acoustiques. Méthode de l'Angle de Réflexion des Etats-Unis d'Amérique; Méthode de l'Onde stationnaire). *Journal of Franklin Institute*, March 1924, Vol. 197, pp. 323-354, and *Hydrographic Review*. Vol. II, N° 1, Monaco, Nov. 1924, p. 93. *Revue Hydrographique*, Vol. II, N° 1, Monaco, Nov. 1924, p. 93.

1924. A.B. WOOD & J.M. FORD. - The phonic Chronometer. (Le Chronomètre phonique). *Journal of Scientific Instruments*, Vol. I, N° 6, Mars 1924, et *Revue Hydrographique*, Vol. V, N° 1, Monaco, Mai 1928, p. 267. *Hydrographic Review*, Vol. V, N° 1, Monaco, May 1928, p. 257.

1924. X... - The acoustic method of depth sounding for navigational purposes. (La méthode acoustique de Sondage des Profondeurs pour les Besoins de la Navigation). *Nature*, Vol. 113, 29, London, March 1924, p. 463.

1924. F.E. SMITH - Modern Navigational Device. (Appareil moderne de Navigation). *Engineering*, Vol. 117, March, 1924, pp. 299-300.

1924. MARTI. - Note sur l'enregistreur continu de sondage en mer par le son. (Note on a continuous Echo-Sounding Recorder). Cf. *Bulletin technique du Bureau Veritas*, Avril 1924.

1924. Dr. H. MAURER. - Über Echolotungen in der amerikanischen Marine. (Les sondages par le son de la Marine Américaine. - On Echo-Soundings in the American Navy). Cf. *Annalen der Hydrographie*, Heft IV, Berlin 1924.

1924. Kapitän I. SCHUBART D.S. - Die Verwendung der Tiefseelotungen für die Navigation mit Hilfe des Echolots. (Emploi pour la navigation des sondages par grands fonds au moyen de l'Echo-Sonde). (Use of deep-sea sounding by echo for navigation purposes). Cf. *Annalen der Hydrographie*, Heft IV, Berlin 1924, p. 73.

1924. Dr. A. SCHUMACHER, D.S. - Hydrographische Bemerkungen und Hilfsmittel zur akustichen Tiefenmessung. (Hydrographic Remarks and Aids to acoustic Depth Finding. - Remarques hydrographiques et Aides pour le Sondage acoustique des Profondeurs). *Annalen der Hydrographie*, Berlin, Avril 1924, pp. 87-95.

1924. BUREAU HYDROGRAPHIQUE INTERNATIONAL. - *Revue Hydrographique*, Vol. I, N° 2, Monaco, Mai 1924, pp. 38-49. *Hydrographic Review*, Vol. I, N° 2, Monaco, May 1924, pp. 39. (France: Sondeur Marti; U.S.H.O. Sonic Depth Finder).

1924. P. LANGEVIN. - L'emploi des ondes ultra-sonores pour le sondage par le son. Conférence faite le 10 Mai 1924 à la Société d'Encouragement des Industries Nationales, Paris. (The Employment of ultra-sonic Waves for Echo Sounding. Lecture delivered on 10th May, 1924, at the "Société d'Encouragement des Industries Nationales", Paris. *Revue Hydrographique*, Vol. II, N° 1, Monaco, Novembre 1924, p. 57. *Hydrographic Review*, Vol. II, N° 1, Monaco, November 1924, p. 57.

1924. Louis V. KING. - Early Canadian experiments in the acoustic method of depth sounding for navigation purposes (1915). (Les premières Expériences canadiennes relatives à la Méthode acoustique de Sondage du Fond de la Mer pour la Navigation (1915). *Mac Gill University*. June 15, and *Nature*, London, July 1924, page 123.

1924. Comm. SINDING. - Behm's Echolot. (Behm's "Echo Sounder". - " Echo-Sonde" de Behm). *Tidsskrift for Søvaesen*, Copenhague, Août 1924, pp. 347-359.
Revue Hydrographique, Vol II, N° 2, Monaco, Mai 1925, p. 161.
Hyd. Review, Vol. II, N° 2, Monaco, May 1925, p. 155.

1924. DORSEY. - Méthode Optique pour mesurer les petits intervalles de temps - Sondage - Fathomètre - (Optical Method for Measuring small intervals of time - Sounding - Fathometer) Cf *Journal of the Optical Society of America*. September 1924, p. 351.

1924. Dr H. MAURER. - Das Englische Echolot. (The English Echo-Sounder. - L'Echo-Sonde anglaise). *Annalen der Hydrographie*, etc, Berlin, September 1924, p .220.

1924. BUREAU VERITAS. - Le sondage par écho, système Behm. (Echo Sounding, Behm System). *Bulletin Technique du Bureau Veritas*, Paris, Septembre 1924 pp. 161-164.

1924. BUREAU VERITAS. - Quelques applications des ondes ultra-sonores. (Some Applications of the ultra-sonic Waves). Pêches Maritimes ,Paris, 4 Octobre 1924, pp. 692-693.

* 1924. E.A. ECKARDT. - Accurate determination of the speed of sound in sea--water. (Détermination précise de la vitesse du Son dans l'Eau de Mer). *Phys. Review*, October 1924, Vol. 24, page 452.

1924. BUREAU HYDROGRAPHIQUE INTERNATIONAL. - Le sondage par le son. (Echo Sounding). *Publication spéciale N°* 3, Oct. 1924 et aussi *Revue Hydrographique*, Vol. II, N°, 1, Nov. 1924, pp. 51-121. (Appareil Langevin à Quartz Piézo-Electrique).
Hydrographic Review, Vol. II, N° 1, No 1, Nov. 1924, pp. 51-121.

1924. ALLEMAGNE. - *Zeitschrift des Vereins deutscher Ingenieure*, Band 68, 1924, p. 1132.

1924. Prof. Mario TENANI. - Stato attuale del problema dello scandaglio acustico. (Present State of the Echo Sounding Problem. - Etat actuel du Problème du Sondage par le son). *Rivista Marittima*, Roma, Nov. 1924, pp. 319.382.

1924 Dr Bruno SCHULZ. - Geschichte und Stand der Entwickiung des Behmlotes unter besonderer Berücksichtigung der Lotungen auf D.S. "Hansa", Hamburg-Amerika Linie. (History and State of Development of the Behm Sounder with special Reference to the Soundings carried out on the *Hansa*, Hamburg-America Line. - Histoire et Etat du Développement du Sondeur Behm, en tenant particulièrement compte des Sondes effectuées à bord de l'*Hansa* de la Hamburg-Amerika Linie). *Annalen der Hydrographie und Maritimen Meteorologie*, Heft XI und XII, Berlin; 1924, pp. 254-271 & 289-300.

1924. Lieutenant de vaisseau Georgio CICOGNA. - Le esperienze di scandaglio col suono a bordo della R.N. "San Marco". (The Echo-Sounding Experiments carried out on H.I.M.S. *San Marco*). - Les Expériences de Sondage par le Son effectuées à bord du Navire de la Marine Royale Italienne *San Marco*). *Rivista Marittima*, Roma, Décembre 1924, pp. 657-680 ; Janvier 1925, pp. 51-78.

1924. Dr H.C. HAYES. - The application of acoustics to submarine surveying. (L'application de l'Acoustique aux Levés sous-marins). *Geographical Review*, New York, XIV, 1924, pp. 681-693.

1924. W.G. CADY. - Piézo-Electric Crystal Oscillators. (Oscillateurs piézo-électriques à Cristal). *Proceedings Inst. Radio Engineers*. 12 805, 1924.

* 1925. H. LAMB. - The Dynamical Theory of sound. (La Théorie dynamique du Son). Arnold, London, 1925.

* 1925. Dr C. BRAAK. - Diepteloodingen in den Indischen Archipel (Depth Soundings in the East Indian Archipelago. - Sondage des Profondeurs dans l'Archipel des Indes Orientales). *Verhandelingen*, N° 17. Kon. Mag. en Meteor. Observatorium te Batavia, 1925.

1925. Dr H.C. HAYES. - The Behm Echo Depth-finder. (Le Sondeur acoutisque Behm). *Nautical Magazine*, Janvier 1925, pp. 53-59.

1925. Dr Bruno SCHULZ. - Stand und Bedeutung der Echolotfrage. (Present State and Importance of the Echo-Sounder Question. - Etat actuel et Importance de la Question du Sondage par le Son). *Tijdschrift van het koninklijk Nederlandsch Aardrijkskundig Genootschap*. Leiden, Janvier 1925, pp. 85-103.

1925. H.T. FERRAR. - Soundings in the seas around New Zealand (Sondage en Mer autour de la Nouvelle-Zélande). 1 chart. Cf. *The New Zealand Journal of Science and Technology*, Feb. 1925, pp. 285-297. *See The Geographical Journal*, London. Dec. 1925 pp. 571.

1925. BUREAU HYDROGAPHIQUE INTERNATIONAL. - Le Sondage par Echo. *Publication spéciale N° 4*, Mars 1925, et *Revue Hydrographique*, Vol. II, N° 2 Mai 1925, p. 141: Le Sondage par Echo (III). (Appareil de Fessenden, Appareil Marti, Sonic Depth Finder, Echo-Sonde de Behm, Sondeur Behm à enregistrement photographique, Bombette et Sondages par explosion). *Hydrographic Review*, Vol. II, N° 2, May 1925, p. 135: Echo Sounding (III). (Fessenden's apparatus, Marti's apparatus, Sonic Depth Finder, Behm's echo-sounder, Behm's sounding machine with photographic recorder, small bombs and soundings by explosions).

1925. J.H.R. SCHOO. - Diepzeekabels en Echoloodingen. (Deep-Sea Cables and Echo-Soundings. - Câbles de haute Mer et les Sondages par le Son). *Tidjschrift Aardr. Genootschap*. Leiden, Mars 1925.

1925. L. PEDRO. - Etat actuel du problème des Sondes Acoustiques. (Present state of Acoustic Sounding) Cf. *Bol. del Centr. Nav.*, Mars-Avril 1925, pp. 769-793.

1925. R. ESTRADA. - Los sondadores acústicos. (Acoustic and ultra-acoustic Sounders). (Les sondeurs acoustiques et ultra-acoustiques). *Revista General de Marina*, Madrid. IV, VI, VII, 1925.

* 1925. BUREAU HYDROGRAPHIQUE INTERNATIONAL. - Vitesse du son dans l'eau de mer. *Revue Hydrographique*, Vol. II, N° 2, Monaco. Mai 1925, p. 191. Velocity of propagation of sound through sea-water. *Hydrographic Review*, Vol. II, N° 2, Monaco, May 1925, p. 183.

1925. Campagne d'Hydrographie de l'"Ammiraglio Magnaghi" (Sondages par le Son. Analyseur optique de Sondage, système Langevin-Florisson). (Surveying cruise of the "Ammiraglio Magnaghi". Echo Soundings. Sounding optical analyser of Langevin-Florisson system). I illust. Cf. *Revue Maritime*, Paris, Juillet 1925, 118-120.

1925. La Ascoltazione Stereoacustica. (L'écoute stéréoacoustique) (Stereoacoustics). Cf. *Rivista Marittima*, Roma, Luglio-Agosto, 1925, pp. 369-378.

1925. Bruno SCHULZ. - Weitere Versuche mit dem Behmlot. (Further experiments with the Behm Sounding Machine) (Expériences ultérieures avec le Sondeur Behm). Cf. *Annalen der Hydr. u. Mar. Meter.*, Berlin, IX-1925, pp. 288-291.

1925. ECHO SOUNDING IN THE PACIFIC OCEAN. - (Sondage acoustique dans l'Océan Pacifique). Cf. *Nature*, London, November 28th 1925. p. 798.

1926. P.P. PALETZKII. - L'écho-sondeur ultra-sonore. (The super-sonic Echo-Sounder). Zapiski po Ghidrografii, Leningrad, Vol. II, 1926.

1926. Dr Ing. Richard BERGER. - Die Schalltechnik. (The Technique of Sound. - La Technique du Son). Friedr. Vieweg & Sohn Akt. Ges., Braunschweig, 1926, pp. 107-108 (Fessenden Oscillator, etc. - Oscillateur Fessenden, etc.).

1026. E. LÜBKE. - Über die neusten Wasserschallapparate und ihre Anwendungen. (Sur les nouveaux appareils hydrophoniques et leur emploi) (On the latest submarine sound appliances and their use). In-8°, 29 pages, 26 figures. Published by Boysen & Maasch, Hamburg, 1926. Price: Marks 1.50.

1926. Alan JONES & B.S. SMITH. - Echo Sounding. (Admiralty Handbook on shallow water type, Mark II). (Le Sondage par Echo. Manuel de l'Amirauté concernant le modèle pour faibles profondeurs, Type II). *Hydrographic Department*, N° 279, 12 pages, 9 pl. Published by H.M. Stationery Office, London June 1926.

1926. Henrik RENQVIST. - Ekolodning (Echo-Sounding). Le Sondage par le son, 20 pages. 12 fig. *Andra Periodiska Forskaremötet* 11-14 I, Helsingfors, 1926.

1926. R.W. BOYLE & G.B. TAYLOR. - Reflecting powers of various materials for ultrasonic waves. (Pouvoir réflecteur de divers matériaux pour les ondes ultrasonores). 13 pages, 3 fig. Published by the Royal Society of Canada, Ottawa, 1926.

1926. R.W. BOYLE & C.D. REID. - Practical Experiments on the detection of Icebergs and on sounding by means of an ultrasonic beam. (Expériences pratiques sur la détection des icebergs et sur le sondage au moyen d'un faisceau d'ultrasons). 11 pages, 4 fig. *Proceedings of the Royal Society of Canada*, Vol. XX. Published by the Royal Society of Canada, Ottawa, 1926.

1926. DIE DEUTSCHE ATLANTISCHE EXPEDITION 1925 DES VERMESSUNGS - und FORSCHUNGSSCHIFFES "METEOR". Über die akustichen Lotungen des Forschungsschiffs "Meteor". (The German Atlantic Expedition of the Surveying and Exploring Vessel "Meteor", in 1925. Concerning echo-soundings of the "Meteor". (L'Expédition Atlantique Allemande du navire explorateur et hydrographe "Meteor", en 1925. Au sujet des sondages acoustiques du navire explorateur "Meteor" In-8°, 19 pages and charts. Published by Mittler und Sohn. Berlin, 1926.

1926. FREIHERR v. RECKUM. - Die akustichen Tiefseelote. (The acoustic Deep-Sea Sounders. - Les sondeurs acoustiques pour grands Fonds). Die Deutsche Atlantische Expedition auf dem V.F. "Meteor"). *Annalen der Hydrographie*, Berlin, 1926, p. 89.

1926. SONDAGE PAR LE SON (IV). - Sondeur ultra-sonore, système Langevin-Florisson avec Analyseur Optique. Enregistreur graphique Marti. Sondeur par Echo (Modèle de l'Amirauté Britannique). *Revue Hydrographique*, Vol. III, N° 2, Monaco, Juillet 1926, p. 75. Echo-Sounding (IV). Ultra-Sonic sounding machine, Langevin-Florisson system, with optical analyser. - The Marti sounding. recorder. Echo sounder (Bristish Admiralty Pattern). *Hydrographic Review*, Vol. III. N° 2, Monaco, July 1926, p. 75.

1926. DAMMEYER. - Schallotungen zwischen Schottland und Island. (Sondage par le son entre l'Ecosse et l'Islande. - Echo sounding between Scotland and Iceland). Cf. *Annalen der Hydrogr. und Mar. Meteor.*, Berlin, Heft VIII, 1926, p. 319.

1926. ECHO SOUNDING IN THE INDIAN OCEAN SOUTH OF JAVA. (Sondage par le son dans l'Océan Indien au Sud de Java). Cf. *The Geographical Journal*, London, August 1926, p. 172.

1926. Dr. H. MAURER. - Echolotung bei geneigtem und stark bewegtem Bodenprofil. (Echo sounding on a slanting or much accidented bottom. - Le Sondage par le son par fond à profil incliné ou accidenté). Cf. *Annalen der Hydrog. und Mar. Meteor.*, Berlin, Heft IX, 1926, pp. 336-340, Heft X, 1926. pp. 391.

1926. A.S. EVE. - A problem in under-water acoustics. (Un problème d'acoustique sous-marine). Cf. *Journal of the Franklin Institute*, Philadelphia, Nov. 1926, pp. 627-635.

1926. Harvey C. HAYES. - Perfectionnements récents des appareils acoustiques pour la mesure des profondeurs. (Recent Developments in acoustical Depth-Finding Apparatus). *Bulletin of the National Research Council*, Washington Nov. 1926, p. 112-116, et *Revue Hydrographique*, Vol. IV. N° 2, Monaco. Novembre 1927, p. 211. *Hydrographic Review*, Vol. IV, N° 2, Monaco, November 1927, p. 205.

1926. DEVELOPMENTS IN THE USE OF ECHO SOUNDING APPARATUS. - (Extension de l'emploi des appareils de sondage par le son). Cf. *Nature*. London, Dec. 11, 1926. pp. 846-848.

* 1926. N.H. HECK and Jerry H. SERVICE. - Correct Velocities for Echo sounding in the Pacific Ocean. - Corrections à apporter à la Vitesse du Son pour le Sondage par le Son dans l'Océan Pacifique). *Science*, New Series, Vol. 64, page 627, December 24, 1926, and *Hydrographic Review*, Vol. IV, N° 1, Monaco, May 1927, p. 229. *Revue Hydrographique*, Vol. IV, N° 1, Monaco, Mai 1927, p. 253.

1926. L.W. MC. KEEHAN. - Magnetostriction. (La Contraction magnétique). *Journal of the Franklin Institute*, Vol. 202, N° 6, Philadelphia, December 1926, pp. 737-773.

1927. FREIHERR von RECKUM. - Bericht über die akustichen Lotungen. (Report on the acoustic Soundings. - Rapport sur les Sondes acoustiques). Die Deutsche Atlantische Expedition. III Bericht. *Zeitschrift für Erdkunde zu Berlin*, 1927, p. 158.

* 1927. Donald J. MATTHEWS. -Tables for the velocity of sound in pure water and sea water for use in echo-sounding and sound-ranging. (Tables de la vitesse du son dans l'eau douce et dans l'eau de mer, pour les sondages et le repérage par le son). In-8°, 29 pp. 1 carte. *Hydrographic Department. Admiralty* (*H.D.* 282). Published by H.M. Stationery Office, London, 1927. Price : 1 shilling net. Also *Hydrographic Review*, Vol. V, N° 1, Monaco, May 1928, p. 277. *Revue Hydrographique*, Vol. V, N° 1, Monaco, Mai 1928, p. 289.

1927. C. FLORRISON. - Les applications des ultra-sons à la navigation. (The Applications of ultra-audible Sounds to Navigation). *Bulletin Association Tech. Mar. et Aér.* Paris, vol. 31, 1927.

1927. H. MAURER. - Zur Echolotung grosser Tiefen. (Echo sounding in great depth. - Les sondages par le son pour grandes profondeurs). Cf. *Annalen der Hydrog. u. Mar. Meteor.*, Heft III, Berlin, 1927, p. 85.

1927. Filippo ORTALDA. - Sull'impiego degli scandagli acustici a bordo del naviglio da pesca. (On echo-sounding on board a fishing smack. - De l'emploi des sondages acoustiques à bord des navires de pêche). *Rivista Marittima,* Mai, 1927, pp. 525-526.

1927. L'UTILISATION DES ULTRA-SONS PAR LES CHALUTIERS. (The utilisation of ultra-sounds by trawlers). Cf. *La Revue Maritime,* Paris, Juillet 1927, p. 141.

1927. NOUVEAUX DISPOSITIFS DE FIXATION DES PROJECTEURS ULTRA-SONORES DE SONDAGES. (New devices for fixing ultra-sonic sounding projectors). Cf. *La Revue Maritime.* Paris, Juillet 1927, pp. 90-93.

1927. M. TENANI. - Nuovi progressi del problema dello scandaglio acustico. (Nouveaux progrès du problème des sondages acoustiques. - Latest progress in the problem of acoustic soundings). Cf. *Rivista Marittima,* Rome, Juillet-Août 1927, pp. 226-230.

* 1927. R.W. WOOD, A.L. LOOMIS, F.C. HUBBARD. A sonic interferometer for Liquids. (Interféromètre acoustique pour Liquides). *Nature,* London, Aug. 6, 1927, p. 189.

1927. SONDAGE PAR ULTRA-SON (Ultra-sonic Sounding). Rapport de la section internationale d'Océanographie physique, Prague. Septembre 1927. *Bulletin N° 11,* 8°, pp. 71-77.

1927. BOECKER. - Ergebnisse von Lotungen mit dem Behm-Tiefseelot auf dem K.D. "Norderney". (Results of Soundings with Behm's Deep-Sea Sounder. - Résultats de Sondages avec le Sondeur pour grands Fonds de Behm). *Annalen der Hydrog.,* Berlin, 1927. p. 237.

1927. BESTEMMELSE AF HAVDYBDER VED EKKOLOD OG TERMOMETER. (Détermination des profondeurs abyssales au moyen des sondages par le son et du thermomètre - Determination of deep sea depths by echo sounding and thermometer). Cf. *Geografisk Tidsskrift,* Copenhague, Sept. 1927, p. 203.

1927. E.G. RICHARDSON. - Sound. (Le Son). 286 pp. 98 figs. Published by Edward Arnold, 41 Maddox Stret, London. Price: 15 shillings. Cf. Review in *La Nature,* Paris, Oct. 15, 1927, p. 380.

1927. Camille VALLAUX. - Les sondages par l'écho et leurs applications à la géographie des mers. (Echo soundings and their application to the geography of the seas). Cf. *Revue Scientifique*, Paris, N° 20, Oct. 22, 1927, pp. 617-625. Cf. *La Revue Maritime,* Paris, Décembre 1927, p. 852.

1927. LE REPÉRAGE ACOUSTIQUE. A propos de bruits parasites ultra-sonores. *Revue Hydrographique.* Vol. IV, N° 2, Novembre 1927, p. 161. Sound Ranging with reference to ultra-sonic parasitic noises. *Hydrographic Review,* Vol. IV, N° 2, November 1927, page 157.

1928. Jerry H. SERVICE. - Measurement of Salinity of Sea Water. (Mesure de la Salinité de l'Eau de Mer). *U.S. Coast and Geodetic Survey Special Publication N° 147.* In-8°, 20 pp. 8 fig. and tables. Washington, Government Printing Office. 1928. Price: 10 cents. *Hydrographic Review,* Vol. VI, N° 2, Monaco, Novemb. 1929, p. 227. *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, p. 235.

1928. I.J. MAHER & R.F. LUCE. - Radio-acoustic position finding. (Détermination du Point par Procédé radio-acoustique). *U.S. Coast and Geodetic Survey Special Publication,* N° 146, Washington, Government Printing Office, 1928. Price: 20 cents.

1928. W.G. CADY. - Bibliography on Piezo-Electricity. (Bibliographie concernant la Piézo-Electricité). *Proc. Inst. Radio Engrs.,* 1928, 16, 521.

1928. F. BEDEAU. Le Quartz Piézo-Electrique et ses applications dans la technique des ondes hertziennes. (Piezo-electric quartz and its application to the technics of Hertzian waves). In-8°, 63 pp. ill. *Fasc. VI du Mémorial des Sciences Physiques.* Publié par Gauthier-Villars, Paris, 1928. Prix: 15 francs.

1928. G.W. LITTLEHALES. - Contribution to the Configuration of the basin of the Pacific Ocean from the "Trans-Pacific depth survey by sound" carried out by the U.S. Fleet in 1925 and from other American sources. (Contribution à la configuration du bassin de l'Océan Pacifique d'après le "Trans-Pacific" Depth Survey by sound", exécuté par la Marine des Etats-Unis en 1925 et d'après d'autres sources américaines). Cf. *Report of Proceedings of the Third Pan-Pacific Science Congress, Tokyo,* 1928, pp. 210-213.

* 1928. N.H. HECK & J.H. SERVICE. - Correct values of the velocity of sound for echo soundings in the Pacific Ocean. (Valeurs exactes de la vitesse du son pour les sondages par écho dans l'Océan Pacifique). Cf. *Report of Proceedings of the 3rd Pan-Pacific Science Congress,* Tokyo, 1928, pp. 202-204.

1928. H. MAURER. - Die Emden Tiefe (The "Emden Deep". - La "Fosse de l'Emden". *Zschr. d. Ges. f. Erdk.* Berlin, 1928, p. 248.

1928. F. SPIESS. - Die Meteor Fahrt. (The Voyage of the *Meteor.* - La Croisière du *Meteor*). *Forschungen und Ergebnisse der Deutschen Atlantischen Expedition* 1925-1927. Berlin, 1928.

1928. LO SVILUPPO E L'IMPORTANZA DELLO SCANDAGLIO ACUSTICO PER LA MARINA MERCANTILE IN BASE AI PRATICI ESPERIMENTI DEGLI ULTIMI ANNI. (Le développement et l'importance du sondage acoustique pour la marine marchande, d'après l'expérience pratique de ces dernières années. - The development and importance of acoustic sounding in the mercantile marine, from practical experience in recent years). Cf. *Rivista Marittima,* Rome, Feb. 1928, pp. 525-535.

* 1928. BUREAU HYDROGRAPHIQUE INTERNATIONAL. - Vitesse du son dans l'eau de mer. Inscription sur les cartes des sondes obtenues par le son. (Velocity of Sound in Sea Water. Insertion of Echo-Soundings on Charts). *Bulletin Hydrographique International (International Hydrographic Bulletin),* Monaco, 1928: N° II, p. 29; N° IV, p. 84; N° V, p. 115; N° VI, p. 147; N° IX, p. 247.

1928. LE SONDAGE PAR ULTRA-SON. (Ultra-sonic sounding). Cf. *La Revue Maritime,* Paris, Avril 1928, pp. 509-510.

1928. CENTRALISATION DES SONDES OBTENUES PAR LE SON. (Centralisation of Echo-Soundings). *Bulletin Hydrographique International. (International Hydrographic Bulletin),* Monaco, N° IV, Avril 1928, p. 82; N° VII, Juillet 1928, p. 163.

1928. H. MAURER. — Les sondages du navire explorateur *Meteor* et l'art nautique. (The Soundings of the Exploring Vessel *Meteor* and nautical Science). *Revue Hydrographique,* Vol. V, N° I, Monaco, 1928, p. 171. *Hydrographic Review,* Vol. V, N° I, Monaco, 1928, p. 167.

1928. SONDAGE PAR LE SON (V). - "Echo-sounder" de l'Amirauté Britannique. Fathometer de la Submarine Signal C°, Boston. Atlas-Lot des Atlas-Werke de Brême. Echolot de la Signal-Gesellschaft de Kiel. *Revue Hydrographique,* Vol. V, N° 1, Monaco, Mai 1928, p. 135. — ECHO-SOUNDING (V). - The British Admiralty Echo Sounder. Fathometer of the Submarine Signal Corporation, Boston. Atlas-Lot of the Atlas-Werke, Bremen. Echolot of the Signal-Gesellschaft of Kiel *Hydrographic Review,* Vol. V, N° 1, Monaco, May 1928, page 131.

1928. Ing. Hyd. P. MARTI. - Méthodes Acoustiques. Rapports et Procès-Verbaux de la Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée. (Acoustic Methods. Reports of Proceedings and Memoranda of the Meetings of the International Committee for the Scientific Exploration of the Medi-

terranean Sea). Vol. III, Paris, Mai 1928, p. 31. Expériences de propagation d'ondes sonores sous-marines, *Revue Hydrographique,* Vol. IX, N° 1, Monaco, Mai 1932, p. 188. Experiments with reference to the propagation of submarine sound-waves. *Hydrographic Review,* Vol. IX, N° 1, Monaco, May 1932, p. 183.

1928. Réduction des sondages. Correction de pente, abaque du U.S. Coast and Geodetic Survey de 1927. *Revue Hydrographique,* Vol. V, N° 1, Monaco Mai 1928, p. 169. — Echo-Sounding correction for slope, U.S. Coast and Geodetic Survey Diagram of 1927. *Hydrographic Review,* Vol. V, N° 1, Monaco, May 1928, p. 164.

1928. R.W. BOYLE. - Ultrasonics. (Les Ultra-Sons). *Science Progress,* July 1928.

1928. Kapitän z. See. A.D. SCHWEPPE. - Die Auswertung von Echolotungen in den Seekarten. (The Utilisation of Echo Soundings on Charts. - L'Utilisation des Sondes par le Son sur les Cartes marines). *Annalen der Hydrographie usw.* Heft X. Berlin. 1928, p. 317.

1928. MODERN METHODS IN HYDROGRAPHIC SURVEYING (Echo Sounding). (Les Méthodes modernes dans le levé hydrographique) (Sondage acoustique). Cf. *Nautical Magazine,* London, October 1928. Adv. p. 10.

1928. Suzanne VEIL. - Les ondes ultra-sonores. (Super-sonic Waves). *Revue Scientifique III.* N° 19. Paris, 13 Octobre 1928.

1928. Dr. H. MAURER. - Können die bei Echolotungen gefundenen Echoabstände auf wahre Tiefen umgerechnet werden ? (Can the Echo Ranges found in Echo Sounding be transformed into true Depths ? - Les Distances d'Echo trouvées au Sondage par le Son peuvent-elles être transformées en Profondeurs vraies?). *Annalen der Hydrographie usw.* Heft XI, Berlin, 1928, p. 347).

1928. Jerry H. SERVICE. - Phénomènes constatés à propos de la détermination du point par la méthode radio-acoustique ou des sondages par le son. Protection des hydrophones. *Revue Hydrographique,* Vol. V, N° 2, Monaco, Novembre 1928, p. 147. - Phenomena observed in connection with radio-acoustic position finding and echo sounding. Shielding of the hydrophones. *Hydrographic Review,* Vol. V, N° 2, Monaco, November 1928, p. 141.

1928. Sondage par le Son (VI). Sondeur ultra-sonore système Langevin-Florisson (suite). Sondeurs acoustiques par chocs et détonations, système Marti, 1927. Sondeurs acoustiques Behm, type IV-A, IV-S et IV-N. *Revue Hydrographique,* Vol. V, N° 2, Monaco, Novembre 1928, p. 115. — Echo-Sounding (VI). Ultra-sonic sounding machine Langevin-Florisson. Acoustic sounding apparatus by sucessive shocks or detonations (Marti system 1927). The Behm Echo Sounder, types IV A, IV S and IV N. *Hydrographic Review,* Vol. V, N° 2, Monaco, November 1928, p. 107.

1928. J.-B. CHARCOT. - Sur un dispositif permettant le sondage acoustique dans les régions polaires. (On an arrangement enabling acoustic soundings to be obtained in the polar regions). Cf. *Comptes Rendus de l'Académie des Sciences,* Paris, 26 décembre 1928, p. 1269.

* 1928. Jerry H. SERVICE. - Transmission of sound through sea-water. *Journal of the Franklin Institute,* Vol. 206, N° 6, Philadelphia, December 1928, pp. 779-807. Cf. *Hydrographic Review,* Vol. VI, N° 2, Monaco, November 1929, p. 228. La Transmission du son à travers l'eau de mer. Cf. *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, p. 236.

1929. P. LANGEVIN. - Sur le mirage ultra-sonore. (On the ultra-sonic mirage). In-8vo. 6 pp. ill. Imprimerie Chaix, Paris, 1929, et *Bulletin de l'Association Technique Maritime et Aéronautique,* Paris, Juin 1929. Voir aussi *Revue Hydrographique,* Vol. VIII, N° 1, Monaco, Mai 1931, p. 150. - See *Hydrographic Review,* Vol. VIII, N° 1, Monaco, May 1931, p. 140.

1929. K.V. UKHOV. - Zvoukovoe ismerenie gloubin. (Sonic measurement of depths. - La Mesure acoustique des Profondeurs). Gidrografitcheskoe Upravlenie, Leningrad, 1929.

1929. DU COS DE SAINT-BARTHELEMY & l'Ing. Hyd. Principal M.H. CATHENOD. - Montage et conduite de l'appareil de sondage par ultra-son utilisé à bord des bâtiments hydrographes. (Fitting and control of the ultra-sonic sounding machine employed on board surveying vessels). In 8°-82 pp. ill. avec specimen d'enregistrement. Imprimerie Nationale, Paris, 1929. Prix 20 francs.

1929. Francis ANNAY. - Le problème du sondage à la mer. (The Problem of Sounding at Sea). *La Vie Technique et Industrielle*, N° 122, Paris, 1929, pp. 882-888.

1929. Michel GRAMANTIK. - Az Elektrolot villamos visszhangmelio egmerö. (Description of the Sonic Depth Finder "Elektrolot". - Description de l'appareil de sondage acoustique Elektrolot). "*Tenger*", vol. 31, N° 6, Budapest 1929, pp. 192-194.

1929. A. BOUTARIC. - La piézo-électricité. Les applications aux ondes ultra-sonores et à la sécurité des navires. (Piezo-Electricity. Its Application to ultra-sonic Waves and to the Safety of Ships). "*L'Electricien*", Vol. LIX, N° 1477, Paris 1929, pp. 439-442.

1929. R. PALLADINO. - Sul problema idrofonico. (On the Hydrophonic problem. - Sur le problème hydrophonique). Cf. *Rivista Marittima*, Roma, Janvier 1929, pp. 79-101.

1929. SCANDAGLIO ELETTRICO ESPLOSIVO. - (Sondage électrique à explosion. - Electric sounding by means of explosion). Cf. *Rivista Marittima*, Roma, Janvier 1929, pp. 114-116.

1929. G.H. GALLÉ. - Het Echolood Langevin-Florisson. (The acoustic sounding apparatus Langevin-Florisson. - Le Sondeur acoustique Langevin-Florisson). Cf. "*De Zee*" Le Helder, Jan. 1929, p. 26.

1929. TEIXEIRA DINIZ. - Sondagens pelo som. (Echo sounding. - Sondage par le son). Ch. "*Anais do Club Militar Naval*", Lisbon, Jan-Feb. 1929, pp. 92-94.

1929. SOUNDING AT SEA (FATHOMETER). - (Le Sondage en mer (Fathometer). Cf. *Nature*, London, Feb. 2, 1929, pp. 181-182.

* 1929. *Compte Rendu de la Ire Conférence Hydrographique Internationale Extraordinaire, Monaco, Avril 1929*, pages 81 (*), 84, 222, 249, 288, 297, 397.
Report of the Proceedings of the 1st Supplementary International Hydrographic Conference, Monaco, April 1929, pages 80 (*), 83, 218, 245, 284, 293, 395.

1929. CAMBRIDGE INSTRUMENT COMPANY LTD. - Chronographe portatif. *Revue Hydrographique*, Vol. VI, N° 1, Monaco, Mai 1929, p. 241. Portable Chronograph. *Hydrographic Review*, Vol. VI, N° 1, Monaco, May 1929 p. 226.

* 1929. ASAITI MURAMOTO. - Vitesse moyenne du son dans l'eau de mer pour les sondages par grandes profondeurs dans les mers avoisinant le Japon. (The average Velocity of Sound in Sea Water for the Deep-Sea Echo-Soundings in the adjacent Seas of Japan). *Bulletin Hydrographique International*, N° V, Monaco, Mai 1929, p. 118.

1929. HOLWECK & LEJAY. - Etude préliminaire d'un diapason de quartz dans un vide élevé. (Preliminary study of a quartz tuning fork in a high vacuum). Cf. *Comptes Rendus de l'Académie des Sciences*, Paris, 10 Juin 1929, pp. 1541-1543.

1929. Rear-Admiral H.P. DOUGLAS. — Echo Sounding. (Le Sondage par le Son). Cf. *Geographical Journal*. London, July 1929, pp. 47-60.

1929. E.P. TAWILL. - Sur les vibrations suivant l'axe optique dans un quartz piézo-électrique oscillant. (On optical axis vibrations in an oscillating piezo-electric quartz). Ch. *Comptes Rendus de l'Académie des Sciences*, Paris, 23 juillet 1929, pp. 163-164.

1929. R.P.P. LEJAY. - Chronographe de précision. (A Precision Chronograph). *Journal des Observateurs*, Marseille, 15 Août 1929. *Revue Hydrographique*, Vol. VII, N° 1, Monaco, Mai 1930, p. 220. *Hydrographic Review*, Vol. VII, N° 1, Monaco, May 1930, p. 212.

1929. La comunicación y la exploración submarina por las ondas ultra-sonoras. (Submarine communication and exploration by means of ultra-sonic waves. - Communication et exploration sous-marine au moyen des ondes ultra-sonores). Cf. *Revista General de Marina*, Madrid, Agosto 1929, pp. 279-282.

* 1929. E. LÜBCKE. - Vitesse du son dans l'eau de mer. (Velocity of sound in sea weater). *Zeitschrift für Technische Physik*, N° 9, 1929, page 386. Aussi *Revue Hydrographique*, Vol. VII, N° 1, Monaco, 1930, p. 196. *Hydrographic Review*, Vol. VII, N° 1, Monaco, 1930, p. 190.

1929. P. KRUYT. — Korte Beschrijving "Ultra Sonore Echo Dieptemeter" systeem "Langevin-Florisson". (Short description of the Langevin-Florisson depth sounder. - Courte description du Sondeur ultra-sonore Langevin-Florisson). *De Zee,* Le Helder, October 1929, pp. 629-640.

1929. L'Etat actuel du sondage par ultra-sons. (The present state of ultra-sonic sounding). Cf. *La Revue Maritime,* Paris, Octobre 1929, pp. 508-513.

1929. Friedrich Kurt REINSCH. - Le Sondeur Behm-Limnolot. *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, p. 169. The Behm-Limnolot Sounder. *Hydrographic Review,* Vol. VI, N° 2, Monaco, November 1929, p 163.

1929 Dispositif d'Oscillographe pour recherches scientifiques. - *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, p. 221. Oscillograph outfit for scientific Research Work. *Hydrographic Review,* Vol. VI, N° 2, Monaco, November 1929, p. 212.

* 1929. Dr H. MAURER & Cap. de Vaiss. CLAUSSEN. - Lecture on Echo Sounding, International Hydrographic Conference, Monaco, 1929. *Hydrographic Review,* Vol. VI, N° 2, Monaco, November 1929, p. 21. Conférence sur le sondage par écho, Conférence Hydrographique Internationale, Monaco, 1929. *Revue Hydrographique,* Vol. VI, N° 2, Monaco, Novembre 1929, p. 23.

1929. Centralisation des sondes obtenues par le son. (Centralisation of Echo-Soundings). *Bulletin Hydrographique International,* Monaco, N° XI, Novembre 1929, p. 226.

1929. Indicating Acoustic Sounder of the American Navy. (Le Sondeur acoustique Indicateur de la Marine américaine). *U.S. Naval Institute Proceedings,* Annapolis, November 1929, and *Hydrographic Review,* Vol. VII, N° 2, November 1930, p. 112. *Revue Hydrographique,* Vol. VII, N° 2, Monaco, Novembre 1930, p. 109.

* 1930. F. WENNER, E.H. SMITH, F.M. SOULE. - Apparatus for the determination aboard ship of the salinity of sea water by the electrical conductivity method. (Appareil pour déterminer à bord la salinité de l'eau de mer par la méthode de la conductivité électrique). In 8-vo. 20 pp. ill. *Research Paper* N° 223, Superintendent of Documents, Washington, 1930. Price : 10 cents.

1930. Instructions for Echo Sounding gear type 752. (Instructions pour l'appareil de sondage par le son, type 752). In 4°. 22 pp. ill. H.M. Stationery Office, B.R. 209, London, 1930. Pr. 2/6. Cf. *Hydrographic Review,* Vol. VIII, N° 2, p. 181. *Revue Hydrographique,* Vol. VIII, N° 2, Monaco, Novemb. 1931, p. 168.

1930. H. RENQVIST. - Bathymetric Chart of the Bothnian Bay and North Kvark, echo-soundings in the years 1927-1929. (Carte Bathymétrique du Golfe de Bothnie et du North Kvark, Sondages par le Son exécutés de 1927 à 1929). in-8vo. 28 pp. ill. *Merentutkimuslaitoksen,* Helsinki, 1930. *Hydrographic Review,* Vol. IX, N° 1, Monaco, May 1932, p. 254. *Revue Hydrographique,* Vol. IX, N° 1, Monaco, Mai 1932, p. 264.

1930. A.L. SHALOWITZ. - Slope corrections for echo soundings. (Corrections de pente pour le sondage par écho). In 8°. 24 pp. U.S. Coast and Geodetic Survey, *Special Publication N° 165,* Government Printing Office, Washington, 1930. Price 10 cents. Also *Hydrographic Review,* Vol. VII, N° 1, Monaco, May 1930, pp. 82-98. Aussi *Revue Hydrographique,* Vol. VII, N° 1, Monaco, Mai 1930, pp. 83-101.

1930. F.M. SOULE & C.C. ENNIS. - Sonic depth finding on the *Carnegie,* Cruise VII. (Le Sondage par le Son à bord du *Carnegie.* Septième Croisière). *Trans. Amer. Geophys. Union.* 11th Annual Meeting, 1930, pp. 264-274.

1930. Gustav ELFVING. - Zur Reduktion von Echolotungen. (The Reduction of Echo Soundings. - La Réduction des Sondes par Echo). *Havsforskningsinstitutets Skrift N° 69.* Helsinki, 1930.

1930. E. LÜBCKE. - Über neue akustiche Lotverfahren. (New Appliances for Echo Sounding. - Dispositif nouveau pour les sondages acoustiques). *Zentralblatt der Bauverwaltung,* Vol. L, N° 8, Berlin 1930, pp. 166-172.

1930. P. MARTI. - Note relative à l'utilisation du sondage acoustique dans la confection des cartes marines. (Note relative to the Utilisation of acoustic sounding in the Compilation of nautical Charts). Congreso Internacional de Oceanografia & Hidrografia & Hidrologia Continental, Sevilla, Mai 1929, Vol. I, Madrid 1930, pp. 63-75.

1930. R.S. PATTON. - Echo Sounding. (Le Sondage par le Son). *Transac. Am. Geophys. Union,* Xth Meeting, April 1929, XIth Meeting, May 1930. National Research Council, Washington, D.C., 1930, pp. 236-240.

1930. Per COLLINDER. - Echo sounding and other hydrographical observations during an expedition in the Greenland and Barents Sea, 1929. (Le Sondage par le Son et autres Observations hydrographiques faites au Cours d'une Expédition à la Mer du Groënland et à la Mer de Barents, 1929). *Geografiska Annaler,* Heft 2 & 3, Stockholm, 1930.

1930. Centralisation des sondes océaniques obtenues par le son. (Centralisation of Echo-Soundings). *Bulletin Hydrographique International,* Monaco, N° III, Mars 1930, p. 50.

* 1930. H. MAURER. - Die Schallgeschwindigkeit im Seewasser der obersten Schichten. (The Velocity of Sound in Sea Water of the topmost Layers. - La Vitesse du Son dans l'Eau de Mer des Couches supérieures). *Annalen der Hydrographie usw.,* Berlin, 1930, p. 104 et *Bulletin Hydrographique* N° IV, Avril 1930, p. 72.

* 1930. J.H. SERVICE. - Comparison of Velocity of Sound Tables of British Admiralty with those of the U.S. Coast and Geodetic Survey. (Comparaison des Tables de la Vitesse du Son de l'Amirauté Britannique avec les Tables du Coast and Geodetic Survey des Etats-Unis d'Amérique). *Bulletin Ass. of Field Engineers,* Washington, June 1930, page 32.

1930. ECHO SOUNDING (VIII). Echo Sounder of the British Admiralty: shallow water type Mark III and Mark IV. Sondage par le Son (VIII). Echo-Sounder de l'Amirauté Britannique: Shallow Water type Mark III & Mark IV. *Hydrographic Review,* Vol. VII, N° 1, Monaco, May 1930, p. 99. *Revue Hydrographique,* Vol. VII, N° 1, Monaco, Mai 1930, p. 102.

1930. H.P. DOUGLAS. - Echo Soundings and Depths. (Sondage par Echo et Profondeurs). Cf. *Nature,* London, June 14, 1930, p. 893.

1930. M. MARTI. - Note on Acoustic Sounding: Brief History; General conditions for the use of sounding by measuring the echo interval; Descriptions of the instruments at present in existence; Discussion. - Note sur le Sondage Acoustique: Historique; Conditions générales d'emploi du sondage par mesure du temps d'écho; Revue des matériels actuellement établis; Discussion. In 8-vo, 34 pp. ill. Imprimerie Chaix, Paris, 1930, et *Bulletin Association Technique Maritime et Aéronautique,* Paris, Juin 1930, pp. 86-120, et *Revue Hydrographique,* Vol. VIII, N° 1, Monaco, Mai 1931, p. 133. *Hydrographic Review,* Vol. VIII, N° 1, Monaco, May 1931, p. 124.

1930. Dr. H. MAURER. Lotungen der Deutschen Kreuzer *Emden* und *Berlin* und des Vermessungsschiffes *Meteor,* 1927-1929. (Echo-Soundings taken by the German Cruisers *Emden* and *Berlin,* and by the Surveying Vessel *Meteor* from 1927 to 1929. - Sondages par le Son des Croiseurs allemands *Emden* et *Berlin* et du Navire Hydrographe *Meteor,* de 1927 à 1929). *Beiheft zu den Nachrichten für Seefahrer,* Berlin, 1930, et *Bulletin Hydrographique International,* Monaco, N° VI, Juin 1930, p. 134, et N° III, Mars 1932, p. 54.

* 1930. R.W. KNOX. - Velocity of sound in Sea Water. Experiments made by the U.S. Coast and Geodetic Survey. (Vitesse du Son dans l'Eau de Mer. Expériences effectuées par le "Coast and Geodetic Survey" des Etats-Unis d'Amérique). *Field Engineers Bulletin,* Washington, June 1930, and *International Hydrographic Bulletin,* Monaco, N° X, October 1931, p. 251.

1930. H. MAURER. - Über Verbesserung von Echolotungen wegen Bodenneigung. (On corrections to echo soundings due to slope of bottom. - Sur les corrections aux sondes par écho à cause de l'inclinaison du fond). Cf. *Annlen der Hydr. u. Mar. Met.,* Berlin, Sept. 1930, pp. 323-325 & *International Hydrographic Bulletin,* N° X, Monaco, October 1930, p. 226.

* 1930. Vitesse du son dans l'eau de mer. (Velocity of Sound in Sea Water). *Bulletin Hydrographique International,* Monaco, N° X, Octobre 1930, p. 225.

1930. ECHO SOUNDING (IX). - The Langevin-Florisson ultra-sonic sounding machine, small model, fitted with echo-meter; Graphic Acoustic Sounder of the U.S. Navy; Indicating Acoustic sounder of the U.S. Navy; British Admiralty Echo Sounder, Mark IV. - SONDAGE PAR LE SON (IX). Sondeur ultra-sonore

Langevin-Florisson, modèle réduit, muni de l'Echomètre. - Graphic Acoustic Sounder de la Marine Américaine; Indicating Acoustic Sounder de la Marine Américaine; Echo Sounder de l'Amirauté Britannique. Mark IV. *Hydrographic Review,* Vol. VII, N° 2, November 1930 p. 105. *Revue Hydrographique,* Vol. VII, N° 2, November 1930, p. 105. *Revue Hydrographique,* Vol. VII, N° 2, Novembre 1930, p. 106.

1930. Ing. Gén. P. DE VANSSAY DE BLAVOUS. - Slope corrections for echo soundings. (Corrections de pente pour les sondages par le son). *Hydrographic Review,* Vol. VII, N° 2, Monaco, November 1930, p. 50, and Vol. VIII, N° 1, Monaco, May 1931, p. 122. *Revue Hydrographique,* Vol. VII, N° 2, Monaco, Novembre 1930, p. 52 et Vol. VIII, N° 1, Monaco, Mai 1931, p. 131.

1930. W. RIDGE. - Practical echo sounding. The Gulf of Bothnia sounded. (Sondage acoustique pratique. Le sondage du Golfe de Bothnie). Cf. *Nautical Magazine.* London, Dec. 1930, pp. 515-517.

* 1930. H.G. DORSEY. - The transmission of sound through sea water. (La Transmission du Son à travers l'Eau de Mer). *Bulletin of Field Engineers,* Washington, December 1930, p. 28.

* 1930. A.L. SHALOWITZ. Data for studying the transmission of sound through sea water. (Données pour étudier la Transmission du Son à travers l'Eau de Mer). *Bulletin of Field Engineers,* Washington, December 1930. p. 79.

1931. J.-H. HAWLEY. - Hydrographic Manual. (Manuel d'Hydrographie). *Special Publication N° 143,* U.S. Coast and Geodetic Survey, Washington, 1931, pp. 55-78. Price: 45 cents.

1931. Alphonse BERGET. - Sur les sondages par le Son (On Echo Sounding). *Annales de l'Institut Océanographique,* tome X, fascicule I, Paris, 1931, pp. 1-18.

1931. P. VIGOUREUX. - Quartz resonators and oscillators. (Résonateurs et Oscilleurs à Quartz). H.M. Stationery Office, London, 1931. Price: 7 s. 6 d. net.

1931. C.N. HICKMAN. - A portable spark chronograph for either direct or alternating current. (Chronographe portatif à étincelles pour courant continu ou alternatif). *Journal of the Franklin Institute,* Philadelphia, Janvier 1931, p. 59-65. *Hydrographic Review,* Vol. VIII, N° 2, Monaco, November 1931, p. 242. *Revue Hydrographique,* Vol. VIII, N° 2, Monaco, Novembre 1931, p. 258.

1931. F. PINKE. - Echo-Loodingen en Bodemprofielen. (Acoustic soundings and seabed contours. - Sondages acoustiques et profils du fond). Cf. *Tijdschrift van het Kon. Ned. Aardrijkskundig Genootschap,* Leiden, Jan. 1931, pp. 55-60.

1931. P. MÜNSTER. - Rektifisering av Ekkoloddskudd for Skrå Bunn. (Correction to the echo soundings for slope of bottom. - Correction pour l'inclinaison du fond aux sondages par le son). Cf. *Norsk Tidsskrift for Sjövesen,* Horten. Ap. 1931, pp. 160-169.

1931. Un Nouveau Sondeur Ultra-Sonore Langevin-Florisson. A new Langevin-Florisson ultra-sonic sounding apparatus. Cf. *Revue Maritime,* Paris, Juin 1931, pp. 793-797.

1931. P. LANGEVIN. - La directivité en acoustique sous-marine. (Directivity in submarine acoustics). In 8-vo. 11 pp. Cf. Association Technique Maritime et Aéronautique, Session de 1931, Paris, Juin 1931.

1931. P. BIQUARD. Absorption des ondes ultra-sonores par l'eau. (Absorption of ultrasonic waves by water). Cf. *Comptes Rendus de l'Académie des Sciences,* Paris, 27 Juillet 1931, pp. 226-229.

1931. A.L. SHALOWITZ. - Les bases physiques des levés hydrographiques modernes. (The physical Bases of modern hydrographic Surveying). *Proceedings of the National Academy of Sciences,* Vol. 17, N° 8, p. 445/55 Washington, Aug. 1931, and *Hydrographic Review,* Vol. IX, N° 1, Monaco, May 1932, p. 157. *Revue Hydrographique,* Vol. IX, N° I, Monaco, Mai 1932, p. 162.

1931. H .MAURER. - Ueber Neigungsverbesserung der Echolotungen. (On slope corrections for echo soundings. - Sur les corrections de pente pour les sondages par le son). Cf. *Annalen der Hydrographie,* Berlin, Sept. 1931, pp. 341-345.

1931. F.L. HOPWOOD. - Ultrasonics: some properties of inaudible sound. (Utlra-sons: quelques propriétés des fréquences inaudibles). Cf. *Nature,* London, 31 Oct. 1931, pp. 748-751.

1931. Fathometer echo sounding apparatus. (Sondeur par le son Fathomètre). Cf. *Nautical Magazine*, Glasgow, Nov. 1931, pp. 422-423.

1931. ECHO SOUNDING (X). British Admiralty echo sounding gear, type 752; Fathometer of the Submarine Signal Corporation, Boston, universal type 432; Records obtained by means of Marti's continuous recording device in conjunction with ultra-sonic appliances. SONDAGE PAR LE SON (X). Appareil de sondage par le son de l'Amirauté Britannique, type 752; Fathomètre de la Submarine Signal Corporation, Boston, type universel N° 432; Diagrammes d'enregistrement obtenus avec des appareils ultra-sonores à enregistreur Marti. *Hydrographic Review*, Vol. VIII, N° 2, November 1931, p. 184. *Revue Hydrographique*, Vol. VIII, N° 2, Nov. 1931, p. 181.

1931. G.D. COWIE & T.B. REED. - Determination of velocity of sound in sea water in Cape Cod Bay. (Détermination de la vitesse du son dans l'eau de mer dans la Baie du Cap Cod). Cf. *Bulletin of Field Engineers*. N° 4, Washington, Dec. 1931, pp. 88-91. and *Hydrographic Review*, Vol. IX, N° 2, Monaco, November 1932, p. 251. *Revue Hydrographique*, Vol. IX, N° 2, Monaco, Novembre 1932, page 261.

1931. K.T. ADAMS. - Report on Echometer. (Rapport sur l'Echomètre). Cf. *Bulletin of Field Engineers*, N° 4, Washington, Dec. 1931, pp. 81-84.

1931. F.B. SIEMS & H.G. DORSEY. - Notes on Fathometer operation. (Notes sur la Manœuvre du Fathomètre). *Field Engineers Bulletin* N° 4, Washington, Decemb. 1931, pp. 97-106.

1931. H. MAURER. - Echolotungen 1928-30. (Echo Sounding 1928-30. - Le Sondage par le Son, 1928-30). *Beiheft zu den Nachrichten für Seefahrer*, N° 12, Berlin, 1931.

1931. H. MAURER. - Der Echolotschreiber der Britischen Admiralität. (The British Admiralty Echo Depth Recorder. - L'Echo-Sondeur Enregistreur de l'Amirauté Britannique). *Annalen der Hydrographie usw.*, Berlin, 1931, p. 465.

* 1932. D.J. MATTHEWS. - Tables for the determination of the density of sea water under normal pressure. (Tables pour la détermination de la densité de l'eau de mer à la pression normale). In-8vo. 56 pp. A.F. Höst et Fils, Copenhague, 1932.

1932. H.F.P. HERDMAN. - Report on the soundings taken during the *Discovery* investigations 1926/1932. (Rapport sur les Sondes prises au Cours des Recherches du *Discovery*, de 1926 à 1932). *Discovery Reports*, Vol. VI, Cambridge 1932. p. 207.

1932. Floyd M. SOULE. - Echo sounding on the Arctic submarine *Nautilus*. (Sondages par le Son effectués à Bord du Sous-Marin arctique *Nautilus*). Woods Hole Oceanographic Institution. Vol. 2, N° I, pp. 65-76, 1932, and *Field Engineers Bulletin* N° 5, Washington, 1932, pp. 67-69.

1932. C. FLORISSON. - Contribution à l'étude expérimentale du sondage acoustique par écho à bord d'aéronefs bruyants. (Contribution to the experimental study of acoustic sounding by echo on board noisy aircraft). Cf. *Bulletin de l'Association Technique Maritime et Aéronautique*, N° 36, Paris, 1932, pp. 315-329.

1932. N.G. RICKETTS. - The "Marion" Expedition to Davis Strait and Baffin Bay 1928. (Expédition du "Marion" au Détroit de Davis et à la Baie de Baffin en 1928). *Bulletin* N° 19, U.S. Coast Guard, Washington 1932.

1932. CORRECTIONS APPLIED TO ECHO SOUNDINGS. - The "Marion" Expedition to Davis Strait and Baffin Bay 1928. (Corrections appliquées aux sondages par le son. Le voyage du "Marion" au Détroit de Davis et à la Baie de Baffin 1928). *Bulletin* N° 19, U.S. Coast Guard, Washington, 1932, p. 57, and *Hydrographic Review*, Vol. IX, N° 2, Monaco. November 1932, p. 254. *Revue Hydrographique*, Vol. IX, N° 2, Monaco, Novembre 1932, p. 264.

1932 P. MARTI. - Méthodes acoustiques. (Acoustic Methods). *Rapports et procès-verbaux de la Commission Internationale pour l'exploration scientifique de la Mer Méditerranée*, Vol. VII, Paris, 1932, pp. 93-106.

1932. *Report of the Proceedings of the Third International Hydrographic Conference Monaco*, 1932 pages 27, 35, 88, 93, 148, 173, 224, 232, 258, 411. *Comptes Rendus de la Troisième Conférence Hydrographique Internationale, Monaco,* 1932, pages 27, 35, 88, 93, 150, 176, 228, 237, 264, 421.

1932. ACOUSTIC SOUNDING. (Sondage acoustique). Cf. *Nature*, London, Jan, 9, 1932, p. 62.

1932. J.A. SLEE. - Reflecting methods of measuring the depth of the sea. (Méthodes de mesure de la profondeur des mers par écho). Cf. *Journal of the Institute of Electrical Engineers,* London, Feb. 1932, pp. 269-280.

1932. Antonio PEDRONI. - Idrofoni. (Hydrophones. - Hydrophones). *Rivista Marittima*, Mars, Juin, Novembre 1932, et Supplément Juillet, Août, Roma 1934.

1932. H. MAURER. - Echolot-Registrierung. (Echo-sounding record. - Enregistrement des .sondes par écho). Cf. *Annalen der Hydrographie,* Berlin, April 1932 pp. 166-167.

1932. R. DUBOIS & L. LABOUREUR. - On a direct electric chronograph allowing the accurate measurement of very short time intervals. - Sur un chronographe électrique à lecture directe permettant la mesure précise d'intervalles de temps très courts). Cf. *Comptes Rendus de l'Académie des Sciences*, Paris, 9 Mai 1932, pp. 1639-1641. et *Hydrographic Review,* Vol. IX, N° 2, Monaco November 1932, p. 234. *Revue Hydrographique*, Vol. IX, N° 2, Monaco, Novembre 1932, page 243.

1932. Dr ERNST SCHREIBER. - Der Echograph. (Sondeur enregistreur de la Cie Elektroakustik de Kiel. - Recording Echo-Sounder of the Electroakustic Cy of Kiel). *Annalen der Hydrographie und Mar. Meteor.*, Berlin 15 Novembre 1932, pp. 462-465, et *Revue Hydrographique*, Vol. X, N° I, Monaco, Mai 1933, p. 191. *Hydrographic Review*, Vol. X, N° I, Monaco, May 1933 p. 178.

1932. P.M. VAN RIEL. - Ozeanographische Forschung in niederländisch Ostindien. (Oceanographic Researches in the Netherlands East Indies. - Recherches océanographiques aux Indes Néerlandaises). *Zeitschrift der Gesellschaft für Erdkunde*, Berlin, N° 5-6, 1932, p. 208.

1932. Per COLLINDER. - Ekolodning. (Echo Sounding. - Le Sondage par Echo). *Teknisk Tidsskrift N°* 6. Norrköping, 1932.

1932. K. UCHOV. - Deep-sea Echo Sounder after the British Admiralty pattern. (L'appareil de sondage par écho pour les grandes profondeurs d'après le modèle de l'Amirauté Britanniqre). Cf. *Zapiski po Gidrographii,* Leningrad, N° 6, 1932, pp. 29-44.

* 1932. T.B. REED. - Theoritical velocity of sound in sea-water and its practical use in R.A.R. Hydrography with comments by A.L. Shalowitz. (Vitesse théorique du Son dans l'Eau de Mer et son Emploi pratique dans le Repérage par le Son en Hydrographie, accompagné de commentaires par A.L. Shalowitz). *Field Engineers Bulletin N°* 5, Washington. June 1932, pp. 37 & 118.

1932. F.B. SIEMS, F.A. RIDDELL, J.C. TISON, H.G. DORSEY. - Notes on Fathometer operations. (Notes sur l'Emploi du Fathomètre). *Field Engineers Bulletin*, N° 5, Washington, June 1932, pp. 49 & seq.

1932. ECHO SOUNDING FROM AIRCRAFT. (Sondage acoustique à bord d'un aéronef). Cf. *Engineering Abstracts,* London, July 1932, pp. 19-20.

1932. SOUND MEASUREMENT. (Mesure du Son). Cf. *Engineering Abstracts,* London, July 1932, pp. 18-19.

1932. H. MAURER. - Die Verhandlungen über die Echolotungen auf der Dritten Internationalen Hydrographischen Konferenz in Monaco, April 1932. (The Deliberations on Echo Sounding at the Third International Hydrographic Conference, Monaco, April 1932. - Les Délibérations au Sujet du Sondage par le Son à la Troisième Conférence Hydrographique Internationale à Monaco, Avril 1932). *Annalen der Hydrographie usw.*, Vol. LX, N° 10, Berlin, 1932, pp. 423-428.

1932. J.L.H. LUYMES. - Draagloodingen, Echoloodingen en Thermometrische Dieptebepalingen. (Wire soundings, echo soundings and thermometric depth determinations. - Sondages au fil, sondages par écho et détermination des profondeurs au moyen de thermomètres). Cf. *Tijdschrift van het K. Nederlandsch* Aardrijkskundig Genootschap, Leiden, Nov. 1932, pp. 849-856.

1932. Ing. Hyd. Principal P. MARTI. - Détermination de la pente du sol sous-marin par un seul sondage acoustique. (Determination of the Slope of the Sea Bottom by a single acoustic Sounding). Cf. *C.R. de l'Académie des Sciences,* Paris, Août 1932, p. 528. *Hydrographic Review,* Vol. X, N° 2, Monaco, November 1933, p. 172. *Revue Hydrographique,* Vol. X, N° 2, Monaco, Novembre 1933, p. 182.

1932. ECHO SOUNDING XI. - British Admiralty Echo Sounder for H.M.S. "Acadia"; Deep sea recording echo sounding gear for H.M.S. "Challenger"; Description of Special echo gear, Mark VI, for cross-channel steamer.
SONDAGE PAR LE SON XI. - Sondeur par écho de l'Amirauté Britannique de l'"Acadia": Appareil enregistreur de sondage par le son par grandes profondeurs du "Challenger"; Sondeur par écho, Mark VI, pour vapeurs traversant la Manche. *Hydrographic Review* ,Vol. IX, N° 2, Monaco, November 1932, p. 135. *Revue Hydrographique,* Vol. IX, N° 2, Monaco, Novembre 1932, p. 138.

1932. J.H. HAYES. - Report on sea trials of deep water echo sounding gear in H.M.S. *Challenger* and *Ormonde,* with appendix "Depth correction due to gradient". (Rapport sur les essais effectués à la mer avec l'appareil de sondage par le son pour grands fonds à bord des navires *Challenger* et *Ormonde* de la Marine Britannique, avec appendice sur la correction de profondeur due à la pente). *Hydrographic Review,* Vol. X, N° 2, Monaco, November 1933, pp. 130-159. *Revue Hydrographique,* Vol. X, N° 2, Monaco, Novembre 1933, pp. 136-181.

1932. G.T. RUDE & K.T. ADAMS. - The graphic recorder in echo sounding. (L'Enregistreur graphique dans le Sondage par Echo) *Field Engineers Bulletin,* N° 6. Washington, December 1932, p. 57.

1933. Per COLLINDER. - Ekolodningens Metoder och Huvudresultat (Methods of Echo Sounding and the principal Results obtained. - Les Méthodes de Sondage par le Son et les principaux Résultats obtenus). *Meddelanden fran Lunds Universitets Geografiska Institution,* Serie C, N° 89, Stockholm, 1933. *Hydrographic Review,* Vol. XI, N° 2, Monaco, November 1934, p. 63. *Revue Hydrographique,* Vol. XI, N° 2, Monaco, Novembre 1934, p. 65.

1933. H. MAURER und Dr. TH. STOCKS. - Die Echolotungen des "Meteor". (Text und Echolot profile). (The Echo Soudings of the "Meteor" (Text and Profiles). - Les Sondages par le Son du "Meteor" (Texte et Profils). *Wissenschaftliche Ergebnisse der Deutschen Atlantischen Expedition auf dem Forschungs-und Vermessungsschiff "Meteor"* 1925-1927. Band II. Berlin 1933. *Hydrographic Review,* Vol. XI, N° I, Monaco, May 1934, p. 138. *Revue Hydrographique,* Vol. XI, N° I, Monaco, Mai 1934, p. 142.

1933. R. DUBOIS & Cdt. LABOUREUR. - Sondage de mer et balisage des aéroports par signaux acoustiques. (Sea Sounding and Buoyage of Airports by acoustic Signals). *Bulletin Ass. Technique Mar .et Aér.,* Vol. 37, Paris 1933.

1933. G.P. & J.P. Algumas Consideraçoes Sobre a Historia Dos Sondadores. (Some Considerations on the History of sonic Depth Finders. - Quelques Considérations sur l'Histoire des Sondeurs acoustiques). *Anais do Club Militar Naval,* Lisboa. Janv-Fév. 1933, pp. 3-28; Mars-Avril 1933. pp. 57-81; Mai Juin 1933, pp. 75-88.

1933. E.C.M. - Metodi e principali risultati dello scandagliamento acustico. (Methods and principal results of acoustic sounding. - Méthodes et principaux résultats du sondage acoustique). Cf. *Rivista Marittima,* Roma, Mar. 1933, pp. 330-331.

1933. C.C. ENNIS. - (Carnegie Institution of Washington). Use of regional constant correction factors for reduction of Echo soundings. (Emploi de facteurs constants de correction régionaux pour la réduction des sondages par le son). (Extract of *Report of Proceedings of the Fifth Pan-Pacific Science Congress,* Vancouver, June 1933, pp. 2075-82). *Hydrographic Review,* Vol. XII, N° 2, Monaco, November 1935, p. 95. *Revue Hydrographique,* Vol. XII, N° 2, Monaco, Novembre 1935, page 98.

* 1933. Floyd M. SOULE. - Sounding Velocities in the Pacific. (Vitesses du son pour les sondages dans l'Océan Pacifique). (Extract of *Report of Proceedings of 5th Pan-Pacific Science Congress,* Vancouver, June 1933 pp. 873-886). Carnegie Institution of Washington.*Hydrographic Review,* Vol. XII, N° I, Monaco, May 1935 p. 167. *Revue Hydrographique,* Vol. XII, N° I, Monaco, Mai 1935, p. 171.

1933. Rear-Admiral J.D. NARES. - Echo-sounding. (Le Sondage par le son). *Hydrographic Review*, Vol. X, N° I, May 1933, p. 38. *Revue Hydrographique*, Vol. X, N° I, Mai 1933, p. 43.

1933. Ing. Hyd. Général P. DE VANSSAY DE BLAVOUS. - Slope corrections for echo soundings (diagrams). (Corrections de pente pour les sondages par le son (abaques). *Hydrographic Review*, Vol. X, N° I, Monaco, May 1933, p. 41, and corrections in *Hydrographic Review*, Vol. X, N° 2, November 1933, p. 180. *Revue Hydrographique*, Vol. X, N° I, Monaco, Mai 1933, p. 47 et corrections dans *Revue Hydrographique*, Vol. X, N° 2, Novembre 1933., p. 190.

1933. C.C. ENNIS. (Department of Terrestrial Magnetism, Carnegie Institution, Washington). - Note on computation of density of sea-water and on corrections for deep-sea reversing-thermometers. (Note sur le calcul de la densité de l'eau de mer et sur les corrections à apporter aux indications des thermomètres plongeurs à renversement). *Hydrographic Review*, Vol. X, N° I, Monaco, May 1933, p. 131. *Revue Hydrographique*, Vol. X, N° 1, Monaco, Mai 1933, p. 141.

1933. ECHO SOUNDING. - (Sondage par le Son). Cf. *Nautical Magazine*, Glasgow, Sept. 1933, pp. 202-206.

1933. UDEMA. - Voordeel van het echolood. Bankjes met mirder diepte op diep water gevonden. (Advantage of echo-sornding. - Lesser depths discovered in deep water. - Avantage du sondage par le son. Petits fonds découverts en eau profonde). Cf. *De Zee*, Den Helder, Oct. 1933, pp. 585-586.

1933. J. COLMAN. - The Woods Hole Oceanographic Institute. Sonic soundings (Institut Océanographique de Woods Hole. Sondages acoustiques). Cf. *Geographical Journal*, London, Oct. 1933, pp. 326-336.

1933. H. TSCHERNING. - The new ultra-sonic sounders and their use in hydrography. (Les nouveaux sondeurs ultra-sonores et leur emploi en hydrographie). *Hydrographic Review*, Vol. X, N° 2, Monaco, November 1933, p. 166. *Revue Hydrographique*, Vol. X, N° 2, Monaco, Novembre 1933, p. 176.

1933. ECHO SOUNDING XII. - Britsh Admiralty super-sonic shallow water echo sounding gear for boats ; Langevin-Florisson Echometer ; Langevin-Florisson Echoscope. — SONDAGE PAR LE SON XII. - Appareil de sondage par le son supersonique pour petits fonds de l'Amirauté Britannique ; Echomètre Langevin-Florisson ; Echoscope Langevin-Florisson. *Hydrographic Review*, Vol. X, N° 2, November 1933, p. 160. *Revue Hydrographique*, Vol. X N° 2, Novembre 1933, page 170.

1933. A. SÖHOLT. - Ekkolodd. - (The Echo-Sounder. - L'Echo-Sondeur). Cf. *Norsk Tidsskrift for Søvesen*, Horten, Décembre 1933, pp. 460-466.

* 1934 O.W. SWAINSON, G. M.C. ILLWRAITH, K. DYK. - The Velocity and ray paths of sound waves in deep sea water. (Vitesse et propagation des ondes sonores en eau de mer profonde). 20 × 27 cm. 37 pp. ill. U.S. Coast and Geodetic Survey, Washington, 1934.

1934. Introduction to the Reports from the Carlsberg Foundation Oceanographical Expedition round the world 1928-1930. (Introduction aux Rapports de l'Expédition Océanographique autour du Monde de 1928 à 1930 organisée par la Fondation Carlsberg), "Dana" Report N° I, Copenhagen, 1934.

1934. SV. GREVE. - Echo-Sounding. (Sondage par le Son). "Dana" Report N° I. Carlsberg Foundation, Copenhagen, 1934 pp. 79-130.

1934. P. MARTI. - Méthodes Acoustiques. (Acoustic Methods). 5e Rapport. *Procès-verbaux de la Commission Scientifique pour l'Exploration de la Mer Méditerranée*. Vol. VIII, Paris, 1934, pp. 163-166.

1934. Prof. F.A. VENING MEINESZ. - Gravity Expeditions at Sea 1923-1932. (Expéditions gravimétriques en Mer 1923-1932). Vol. II. Publication of the Netherlands Geodetic Commission, J. Waltman Jr. Delft, 1934, p. 87, and *International Hydrographic Bulletin*, N° 2, Monaco, March/April 1935, p. 36.

1934. LARCHWOOD. - How the Echo-Sounder can be useful. (Comment l'Echo-Sondeur peut être utile). Cf. *Nautical Magazine*, Glasgow, April 1934, pp. 318-320.

1934. W.R. GHERARDI. - The topographic activities of the Hydrographic Office of the United States Navy from April 1933 to April 1934. (Les Activités topographiques de l'Hydrographic Office de la Marine des Etats-Unis d'Amérique, d'Avril 1933 à Avril 1934). Fig. 3: *Bathymetric chart of the Carribean Sea,* National Research Council, Part I, Washington D.C., June 1934, p. 193.

* 1934. T.B. REED. - Velocity of sound in sea-water. (Vitesse du Son dans l'Eau de Mer). *Field Engineers Bulletin,* N° 7, Washington, June 1934, p. 115.

1934. ECHO-SOUNDING (XIII). - Germany: Atlas-Echolot, type 20 and type 22 (Atlas-Werke, Bremen); Atlas Echograph - Great Britain : British Admiralty Deep Water Echo Sounding Machine, Standard Pattern, Mark X (Henry Hughes and Son Ltd., London); British Admiralty Silent Super-Sonic Echo Sounder (various types); British Admiralty Boat Super-Sonic Shallow water echo sounding gear, with magneto-striction transmitter. - France : Continuous echo-sounder using rifle shots for deep water use (S. Marti, Montbéliard) (various types); Langevin-Florisson-Touly sounder (S.C.A.M. Paris); Langevin-Florisson sounder combined with Marti recorder; Langevin-Florisson sounder with echometer; Langevin-Florisson sounder with echoscope.
SONDAGE PAR LE SON (XIII). - Allemagne: Atlas-Echolot type 20 et type 22 (Altlas-Werke, Brême); Atlas-Echograph. Grande-Bretagne: Machine à sonder pour grands fonds, modèle courant, Mark X (Henry Hughes & Son Ltd., Londres); Sondeur super-sonique silencieux de l'Amirauté Britannique (divers types); Appareil de sondgae par le son pour petits fonds, à ultra-son, pour embarcation, modèle de l'Amirauté Britannique, à émetteur par contraction électro-magnétique. France: Sondeur acoustique continu par arme à feu pour l'exploration des grandes profondeurs (S. Marti, Montbéliard) (types divers); Sondeur Langevin-Florisson-Touly (S.C.A.M.), Paris); Sondeur Langevin-Florisson conjugué avec enregistreur Marti; Sondeur Langevin-Florisson avec Echomètre ; Sondeur Langevin-Florisson avec Echoscope. *Hydrographic Review,* Vol. XI N° 2, Monaco, November 1934, p. 25. *Revue Hydrographique,* Vol. XI, N° 2, Monaco, Novembre 1934, p. 25.

1934. Paul A. SMITH. - Recent Acoustic Work of the U.S. Coast and Geodetic Survey. (Les Travaux acoustiques récents du Coast and Geodetic Survey des Etats-Unis d'Amérique). *Field Engineers Bulletin* N° 8, Washington, December 1934, p. 60. *Hydrographic Review,* Vol. XII, N° 2, Monaco, November 1935, p. 81. *Revue Hydrographique,* Vol. XII, N° 2, Monaco, Novembre 1935, p. 84.

1935. A. DE GRAMONT. - Recherches sur le quartz piézo-électrique. (Researches on piezo-electric Quartz). Editions de la *Revue d'Optique,* Paris, 1935.

1935. Theodor STOCKS und Georg WÜST. - Die Tiefenverhältnisse des offenen Atlantischen Ozeans. (Depth Conditions in the open Atlantic Ocean. - Etat des grandes Profondeurs de l'Océan Atlantique). *Wiss. Ergebnisse der Deutschen Atlantischen Expedition auf dem* Meteor *1925/27.* Band III. Erster Teil. Walter de Gruyter & C°, Berlin, 1935.

1935. A.B. WOOD, F.D. SMITH & J.A. MC GEACHY. - A magneto-striction echo depth-recorder. (Enregistreur de Sondage par le Son à Contraction magnétique). *Journal of the Institution of Electrical Engineers,* Vol. 76, N° 461, London, 1935, pp. 550-566. *Hydrographic Review,* Vol. XIII, N° 2 Monaco, November 1936, pp. 87-106. *Revue Hydrographique,* Vol. XIII, N° 2, Monaco, Novembre 1936, pp. 90-110.

* 1935. F. PINKE. - Depth Determinations. (Déterminations de Profondeurs). *Wetensch. Uitk. der Snellius-Expeditie 1929-30.* II.-Oceanography, part II, chap. I. Kemink & Zoon, N.V. Utrecht, 1935.

* 1935. S. KISINDO. On the correction to depths of sea obtained by Echo-Sounding. (Sur les Corrections à apporter aux Profondeurs de la Mer obtenues au Moyen du Sondage par le Son). *Suiro Yoho.* N° 14, Tokyo, 1935, pp. 469-471.

* 1935. Willy BEIN, Heinz Günther HIRSEKORN & Lotte MÖLLER. - Konstantenbestimmungen des Meerwassers und Ergebnisse über Wasserkörper. (Détermination of Sea Water Constants and Results re Bodies of Water. - Détermination des Constantes de l'Eau de Mer et Résultats concernant les Bassins liquides). *Veröffentlichungen des Instituts für Meereskunde* N° 28. 240 pp. 45 fig. 14 pl. Mittler und Sohn, Berlin, 1935 et *Bulletin Hydrographique International,* N° I, Jan.-Fév. 1936, p. 8.

1935. DE WERELDREIS VAN HHR. MS. K. XVIII. - The world journey of H.M. K.XVIII. (Le voyage autour du monde du sous-marin K.XVIII de la Marine Royale Néerlandaise). Cf. *Tidschrift v.h.K. Ned. Aardr. Genootschap,* Leiden, Jan. 1935. - pp. 129-131.

1935. A NEW DEPTH SOUNDING RECORDER. (Nouvel enregistreur graphique de sondages). Cf. *Nature,* London, Feb. 9. 1935, p. 227.

1935. C. VALLAUX. - Deep-sea acoustic soundings. (Les sondages acoustiques en mer profonde). Cf. *La Revue Maritime,* Paris, Avril 1935. pp. 433-463.

1935. Rear-Admiral J.A. EDGELL. - False echoes in deep water. (Faux Echos par eau profonde). *Hydrographic Review,* Vol. XII, N° 1, Monaco, May 1935, p. 19. *Revue Hydrographique,* Vol. XII, N° 1, Monaco, Mai 1935, p. 20.

1935. H.H. RUST. - Mehrfach-Reflexionen beim Echoloten auf weichem Grund. (Multiple echoes in sonic sounding on a soft bottom. - Réflexions multiples observées lors du sondage par le son sur fond mou). Cf. *Die Naturwissenschaften,* Berlin, Heft 24, 1935, pp. 387-389. *Hydrographic Review,* Vol. XII, N° 2, Monaco, November 1935, p. 106. *Revue Hydrographique,* Vol. XII, N° 2, Monaco, Nov. 1935, p. 109.

1935. T. STOCKS. - Erkundungen über Art und Schichtung des Meeresbodens mit Hilfe von Hochfrequenz-Echoloten. (Research into the nature and stratification of the sea bottom by means of high-frequencq "Echolot". - Recherches sur la nature et la stratification du fond de la mer au moyen d' « Echolots » à haute fréquence). Cf. *Die Naturwissenschaften,* Berlin, Heft 24, 1935. pp. 383-87. *Hydrographic Review,* Vol. XII, N° 2, Monaco, November 1935 p. 101. *Revue Hydrographique,* Vol. XII, N° 2, Monaco, Novembre 1935, p. 104.

1935. R. JOUAUST. - Le quartz piézo-électrique. (Piezo-electric Quartz). *L'Onde électrique,* Juin 1935.

1935. SYSTEMS OF ECHO SOUNDING. (Les systèmes de sondage par le son). Cf. *Nature,* London, June 1, 1935, pp. 896-900.

1935. O. SUND. - Echo sounding in fishery research. (Le Sondage par le son dans les recherches pour la pêche). Cf. *Nature,* London, June 8, 1935, p. 953.

1935. D.M. PACHER. - La posibilidad de emplear el localizador acústico en la navegación. (The possibility of using the Sound Locator in navigation. - La possibilité d'utiliser le localisateur acoustique en navigation). Cf. *Revista General de Marina,* Madrid, June 1935, pp. 873-880.

1935. HET NIEUWE ECHOLOOD. (The new echo-sounder. - Le nouvel écho-sondeur). Cf. *De Zee,* Den Helder, Jul. 1935, pp. 337-342.

1935. D.E. FEYER. - Über akustiche Vermessung. (On acoustical land-surveying. - Sur l'arpentage acoustique). Cf. *Allgemeine Vermessungs- Nachrichten,* Liebenwerda, 11 Oct. 1935, pp. 505-513.

1935. Herbert G. DORSEY. - The Dorsey Fathometer. (Le Fathomètre Dorsey). *Journal of the Washington Academy of Sciences,* Vol. 25 N° 11, November 1935, and *Field Engineers Bulletin,* N° 8, Washington, December 1934, p. 12.

1935. ECHO-SOUNDING (XIV). - The Dorsey Fathometer (U.S. Coast and Geodetic Survey). Hydrographic Precision Soundings with the Marti hammer-blow sounder. Le Fathomètre Dorsey (U.S. Coast and Geodetic Survey). Sondages de Précision effectués avec le Sondeur par chocs système Marti. *Hydrographic Review,* Vol. XII, N° 2, Monaco, November 1935, p. 50. *Revue Hydrographique,* Vol. XII, N° 2, Monaco, Novembre 1935, p. 50.

* 1935. R. LUCAS. - On the propagation of supersonic sounds in liquids. (Sur la propagation des ultra-sons dans les milieux liquides). Cf. *Comptes Rendus de l'Académie des Sciences,* Paris, 9 Décembre 1935, pp. 1172-1174.

1935 J.M. SMOOK. - Deep sea Electric Bomb. (Bombes à mise de feu électrique pour le repérage en eaux très profondes). Cf. *Field Engineers Bulletin,* Washington, December 1935, pp. 84-86. *Hydrographic Review,* Vol. XIII, N° 2, Monaco, November 1936, p. 140. *Revue Hydrographique,* Vol. XIII, N° 2, Monaco, Novembre 1936, p. 147.

1936. P.S.E. MAXWELL. - Echo-sounding with special reference to Marine Surveying. (Le Sondage par le son et son rapport particulier avec les levés maritimes). 17 × 25 cm. 24 pp. ill. Reprinted from: Reproduit de: *Empire Survey Review,* London, 1935-36, N^{os} 17, 18, 19.

1936. Captain I.F. HUTCHINGS. - Echo-sounding equipment for ships. (Matériel écho-sondeur pour navires). 14 × 21 cm. 30 pp. ill. *Transactions of the Institution of Engineers and Shipbuilders in Scotland,* Glasgow, 1936.

1936. C. FLORISSON. - Supersonic waves and their application. (Les ultra-sons et leurs applications). 16 × 24 cm. 31 pp. ill. *Bulletin de la Société Belge des Electriciens,* Bruxelles, 1936.

* 1936. H.G. DORSEY. - Transmission of sound through sea water. (La Transmission du Son à travers l'Eau de Mer). *Journal Acoustic Society America,* Vol. VII, Menasha, Wis. pp. 287-299.

1936. F. HUGHES. - How they found the *Lusitania.* (Comment fut retrouvée l'épave du *Lusitania*). *Cf. The Nautical Magazine,* Glasgow, Jan. 1936, pp. 33-35.

1936. SONIC SOUNDING INVESTIGATIONS IN THE NORTH PACIFIC OCEAN. (Recherches par le Sondage par le Son dans l'Océan Pacifique Nord). Cf. *The Military Engineer,* Washington, Sept.-Oct. 1936, p. 388.

1936. H. TSCHERNING. - Recent improvements in the ultrasonic echo sounding apparatus. (Récents perfectionnements dans les appareils de sondage par ultra-sons). *Hydrographic Review,* Vol. XIII, N° 2, November 1936, p. 106. *Revue Hydrographique,* Vol. XIII, N° 2, Novembre 1936, p. 111.

1936. ECHO SOUNDING (XV). - New British Admiralty Recorder echo-sounders: M.S. III - M.S. IV - M.S. X - M.S. XII. A Magnetostriction echo depth-recorder. Les nouveaux Echo-Sondeurs enregistreurs de l'Amirauté Britannique: M.S. III - M.S. IV - M.S. X - M.S. XII. Enregistreur de Sondage par le Son à contraction magnétique. *Hydrographic Review,* Vol. XIII, N° 2, Monaco, November 1936, pp. 78-106. *Revue Hydrographique,* Vol. XIII, N° 2, Monaco, Novembre 1936, pp. 80-110.

* 1936. Comm. O.W. SWAINSON. - Velocity and Ray paths of sound waves in sea-water. (Vitesse et Trajectoires des Ondulations sonores dans l'Eau de Mer). *Field Engineers Bulletin,* Washington, December 1936 and *Hydrographic Review,* Vol. XIV, N° 2, Monaco, November 1937, page 93. *Revue Hydrographique,* Vol. XIV, N° 2, Monaco, Novembre 1937, page 97.

1937. P. MARTI. - Les ondes acoustqiues sous-marines. Leur application à l'exploration de la mer. (Submarine acoustic Waves. Their Application to the Exploration of the Seas). *Annales Institut Océanographique.* Vol. XVI, N° 4. Paris, 1937, pp. 361-388.

1937. *Compte Rendu de la 4^{me} Conférence Hydrographique Internationale,* Monaco, 1937, pages 146, 340, 405, 412. - *Report of the Proceedings of the 4th International Hydrographic Conference,* Monaco, 1937, pages 142, 341, 405, 412.

* 1937. Dr. Georg KERNER. - Die Salzgehaltsschwankungen im Oberflächenwasser des Nordatlantischen Ozeans während der Jahre 1920-1931. (Salinity variations in the surface water of the North Atlantic Ocean during the years 1920-1931. - Variations de Salinité des Eaux de surface de l'Océan Atlantique Nord au cours des années 1920-1931). 22 × 30 cm. 19 pp., 5 pl. *Aus dem Archiv der Deutschen Seewarte,* Hamburg, 1937.

1937. Ing. Hydr. Gén. D. COT. - Les procédés récents de Sondage par le son. (Recent Methods of Echo Sounding). *Annuaire du Bureau des Longitudes,* Gauthier-Villars, Paris, 1937. pp. B1-B24.

1937. T. KUYAMA. - Ueber den magnetostriktiven Unterwasserschallempfänger. (On the Magnetostriction submarine Sound Receiving Set. - Récepteur acoustique sous-marin à Contraction magnétique). *Proc. Phys. Math. Soc. Jap.* Série 3, N° 3, Tokyo, 1937.

1937. INTERNATIONAL HYDROGRAPHIC BUREAU. - Insertion on charts of echo soundings and the calibration of echo sounding machines. (Mode d'Insertion sur les cartes des sondages par le son et calibrage des écho-sondeurs). *Hydrographic Review,* Vol. XIV, N° 1, Monaco, May 1937, pp. 71-86. *Revue Hydrographique,* Vol. XIV, N° 1, Monaco, Mai 1937, pp. 73-89.

1937. INTERNATIONAL HYDROGRAPHIC BUREAU. - Plotting and Publication of Echo Soundings. (Rédaction et Publication des sondes obtenues par le son). *Hydrographic Review,* Vol. XIV, N° 1, Monaco, May 1937, pp. 87-96. *Revue Hydrographique,* Vol. XIV, N° 1, Monaco, Mai 1937, pp. 91-100

1937. ECHO SOUNDING (XVI). - Langevin-Touly electrolytic recording system. Outboard oscillators for echo-sounding apparatus. (Enregistreur électrolytique Langevin-Touly. Oscillateur hors bord pour appareil de sondage par le son). *Hydrographic Review,* Vol. XIV, N° 1, Monaco, May 1937, p. 111. *Revue Hydrographique,* Vol. XIV, N° 1, Monaco, Mai 1937, p. 115.

1937. G. OGGIONI. - Ultrasuoni. (Ultra-Sounds. - Ultra-sons). Cf. *Rivista Marittima,* Roma, July-Aug. 1937, pp. 27-31. *Hydrographic Review,* Vol. XIV, N° 2, Monaco, November 1937, p. 207. *Revue Hydrographique,* Vol. XIV, N° 2, Monaco, Novembre 1937, p. 213.

1937. G.T. RUDE. - The Dorsey Fathometer, Sono-radio Buoy & Radio acoustic Ranging. (Le Fathomètre Dorsey, la Bouée radio-sonore. Repérage radio-acoustique). *Hydrographic Review,* Vol. XIV, N° 2, Monaco, November 1937, p. 67. *Revue Hydrographique,* Vol. XIV, N° 2, Monaco, Novembre 1937, p. 65.

1937. ECHO-SOUNDING (XVII). - Universal Echo-Sounder of the British Admiralty, Henry Hughes & Son Ltd. Echo sounding devices presented by the Marconi Sounding Device Company during the IVth International Hydrographic Conference, Monaco, 1937; Marconi Echometer, types 421, 424, 429, 430, Marconi Magneto Striction Equipment, with recorder. — SONDAGE PAR LE SON (XVII). - Universal Echo Sounder de l'Amirauté Britannique, Henry Hughes & Son Ltd. Appareils de sondage par le son présentés par la Compagnie Marconi au cours de la IV[e] Conférence Hydrographique Internationale, Monaco, 1937; Echometer Marconi, types 421, 424, 429, 430, équipement Marconi à magnétostriction, avec enregistreur. *Hydrographic Review,* Vol. XIV, N° 2, Monaco, November 1937, p. 211. *Revue Hydrographique,* Vol. XIV, N° 2, Monaco, Novembre 1937, p. 217.

* 1938. Susuma KUWAHARA. - Velocity of sound in sea-water and calculation of the velocity for use in sonic sounding. (Vitesse du Son dans l'Eau de Mer et Calcul de la Vitesse à utiliser dans le Sondage par le Son). Hydrographic Department, I.J.N., Tokyo, 1938.

* 1938. Donald J. MATTHEWS. - Tables for calculating the specific volume of sea-water under pressure. (Tables pour calculer le volume spécifique de l'eau de mer sous pression). 17 × 25 cm. v. + 67 pp. Conseil Perm. International pour l'Exploration de la Mer, Copenhagen, March 1938. Price: Kr. 5.00. Cf. *Hydrographic Review,* Vol. XV, N° 2, Monaco, November 1938, p. 159. *Revue Hydrographique,* Vol. XV, N° 2, Monaco, Novembre 1938, p. 167.

1938. H. VIGNERON. - Deep-sea soundings. The Geology of the Ocean Floor. (Les sondages profonds en mer. La géologie du fond des océans). Cf. *La Nature,* Paris, 15 Mars 1938, pp. 175-177.

1938. Pierre BIQUARD. - A study of the propagation of ultra-sounds in liquids under pressure. (Etude de la propagation des ultra-sons dans les liquides sous pression). Cf. *C. R. Ac. Sciences,* Paris, 21 Mars 1938, pp. 897-899.

1938. SADARIHO MATSUO. - Investigation of a direct reading depth meter for "pilotage" using a new ultrasonic sounding principle (quasi "modulated frequency." principle). (Etude d'un sondeur à lecture directe. Modèle pour pilotage utilisant un nouveau principe pour le sondage ultra-sonore (à fréquence modulé). *Hydrographic Review,* Vol. XV, N° 1, Monaco, May 1938, p. 33. *Revue Hydrographique,* Vol. XV, N° 1, Monaco, Mai 1938, p. 35.

1938. ECHO SOUNDING (XVIII). - The new British Admiralty recording echo-sounders "Universal", M.S. XII, M.S. XV; Some recent ultra-sonic instruments: Scam-Touly, Langevin-Touly, Marconi, Langevin-Florisson; Marconi magneto-striction supersonic echo sounding equipments; Atlas-Echolot, high-frequency type. — SONDAGE PAR LE SON (XVIII). - Les nouveaux sondeurs par le son de l'Amirauté Britannique "Universel", M.S. XII, M.S. XV; Les appareils récents à ultra-sons: Scam-Touly, Langevin-Touly, Marconi, Langevin-Floris-

son; Les appareils de sondage par le son supersonores à contraction magnétique Marconi; Atlas-Echolot, type à haute fréquence. *Hydrographic Review*, Vol. XV, N° 2, Monaco, November 1938, p. 26. *Revue Hydrographique*, Vol. XV, N° 2, Monaco, Novembre 1938, p. 26.

1938. N.P. HINTON. - The Marconi Magnetostriction supersonic echo-sounder. (Les appareils de sondage par le son supersonores à contraction magnétique Marconi). *Hydrographic Review*, Vol. XV, N° 2, Monaco, November 1938, p. 54. *Revue Hydrographique*, Vol. XV, N° 2, Monaco, Novembre 1938, p. 55).

1938. W. MÖCKEL. - Das Tiefsee-Echolot und seine Bedeutung für die Navigation. (Deep Sea Echo Soundings and their Importance for Navigation. - Les Sondages par le Son par grand Fond et leur Importance pour la Navigation). Cf. *Der Seewart*, Heft 10, Hamburg, 1938, pp. 350-355. *Hydrographic Review*, Vol. XVI, N° 1, Monaco, May, 1939, pp. 117-120. *Revue Hydrographique*, Vol. XVI, N° 1, Monaco, Mai 1939, pp. 119-123.

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N I C E